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Moderately-rapid assessment of alkaline desiccation environmental systems

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MODERATELY-RAPID ASSESSMENT
OF
ALKALINE DESICCATION ENVIRONMENTAL SYSTEMS

A Dissertation

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In

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By

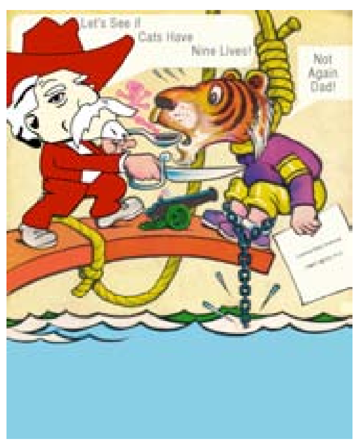
David A. Bates
B.S., Louisiana State University, 1983
M.S., Louisiana State University, 1999
May 2008

This work is first and foremost dedicated to my Dad and Mom for their unwavering support.

My father and mother supported the field phase from 1983 to 1989 when we first started in the Yucatan then later in Central Mexico. I remember when they visited us in Mexico, and then again when they met us at the border in Nuevo Laredo, and helped us haul our Mexican trinkets back home. That was really special. I also, remember receiving letters from Dad while I was in the Yucatan that gave me a good emotional boost. My mom has always been a beautiful example of kindness, compassion, and dedication to others, as seen by her work in the Church and in her daily life. She set the example that motivated me to work as a developmental worker for all these years.

It was my Dad’s work ethic and long-time dedication to his job that exemplified professionalism and instilled in me the work ethic that enabled me to meet the intellectual and rigorous work schedule to accomplish this 27-year project.

Thank you to that Ole Miss Rebel who teamed up with an LSU Tiger. I feel honored to have had you and Archie to be my Saints. You were right about the historic game between our two Alma Maters, after hearing your story time and time again. I do accept that the referee probably cheated in withholding the stop clock allowing the Tigers to unrightfully win that game with two plays in five seconds—an impossible task. So the cat is out the bag, or should I say, the Tiger has been sacked! Go Rebels.



The Rival Alma Mater’s
of the Sponsor of the
Work and the Author:
father and son.

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I would like to acknowledge the organization of Camp, Dresser, and McKee Consulting Engineers for their assistance since 1984 by providing documents from their international on-site library related to their Water and Sanitation for Health(WASH) and Environmental Health Project(EHP) Libraries as part of their U.S. Agency for International Development World Bank Project. I would specifically like to recognize David Donaldson, Dan Campbell, May Yacoob, Eduardo Perez, and other staff members that assisted me. Also, I would like to recognize Eric Evans from Woods End Research Laboratory, the manufacturer of the Solvita kits. The WASH, EHP and Solvita information from these two sources were both used extensively. This acknowledgement serves as a general recognition of the many documents from these two sources that I may have referred to in this report yet not specifically cited. Last but not least this work is written in memory of Dr. Dipak Roy. As my undergraduate civil engineering professor he started me along this path with my first paper on this work. He also accompanied me as part of the American Delegation to the 1984 Venezuela conference that showed me that the Latin American people wanted this research and eagerly received that first humble work. That was the catalyst that got this research going and my non-profit work.

Any omissions or misinterpretations of any cited material was unintentional and solely the responsibility of the author. In my enthusiasm at conveying this material to the reader, I may have taken some grammatical license and I thank the reader in advance for understanding.

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FORWARD

Truly sustainable development is an elusive goal, but what David Bates presents here is an encouraging step toward such a future. His interest in addressing multiple objectives, while attempting to give full attention to each, is indeed a noble sentiment. He has addressed an important topic most of us wish to avoid, that of managing human waste. This topic in itself intersects with ecological and human health issues; water and resource management; and social and cultural perceptions and practices. Finally, Bates has addressed all this within a rural Mexican village, with the limited resources and unique social circumstances of a developing area. Each of these are critical issues to the sustainability of our planet and both the human species and ultimately the other creatures with which we share the Earth. Water management has become a critical resource issue not only in developing but in developed countries, and contributions such as low water toilets are needed. Human health is also critical as increasing population densities invite epidemics. Hence, addressing such issues on a local, and I might add, low cost, basis is similarly important. Reducing human impact on fragile ecosystems is even more necessary at this juncture where humans threaten to cause irreversible extinctions across the globe.

The compost toilet, or more accurately in most of these cases, the alkaline low-water toilet is a practical and useful contribution to these causes. But what makes this work truly unique is the consideration of social and anthropological factors, resulting in a truly synergistic work which addresses not only the technical success but also the social context and sustainability of such efforts. As a biological and ecological engineer, I have spent much of my career sharing the importance of working with, not against, biological and ecological systems as we design and build. Bates addresses not only the biological but the social context without which the long term success of such projects is doubtful. Despite his work of more than a decade, this is really only the beginning of efforts to move toward culturally appropriate, resource efficient, ecologically friendly, and technically sound approaches to development and to human life in all societies. However, his attempts to address the social as well as technological aspects of this work are really a call to action for those already at work in these and related fields, and a call to a new generation to join in the good work that is needed to ensure a sustainable future for all who call Earth their home.

Steven G. Hall, Ph.D., P.E.
(on sabbatical in Yucatan and Baja California, Mexico)
March 2008

This study is an important contribution to the sanitation sector in that it investigates the social as well as technical aspects of a compost toilet system in a Latin American setting. I have followed the sanitation literature for years and nearly all such studies focus on the technical aspects and ignore the social and anthropological aspects which are essential to understand if a sanitation system is to be sustainable.

Dan Campbell, Web Manager
Environmental Health at United States
Agency for International Development

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ABSTRACT

A *moderately-rapid assessment tool* was developed to analyze the waterless desiccation compost toilet investigated in a rural Mexican setting. Over 100 social factors were identified along with the applicable technical factors that influenced the low acceptability of the toilets. A 4-point rating scale was developed to increase the ability and speed of analyzing *both* the social and technical data.

The treatment process was an alkaline-desiccation process with mean pH values of 8.2 ± sd 1.1 and water content of 18.3% ± sd 9.9, which resulted in mean fecal coliform values of 15.0 MPN/g ± sd 31.8, drastically lower than the 1000 MPN/g United States Environmental Protection Agency (USEPA) limit. Alkalinity, not pH, was determined to be the limiting factor in some waste samples, resulting in the need to dilute the waste with local soils. Designs were developed to reduce the unnecessarily long detention times between 0.75 to 4.4 years and improve other features, especially additive use and waste handling.

Solvita® test kits were used to assess compost characteristics. Modifications, made to kit procedures to enable their use, included adjusting pH values and extending the pre-test acclimation period. With low macro-nutrient concentrations, a mean carbon/nitrogen ratio of 14.0 ± sd 6.1, and a mean volatile solids value of 15.9 ± sd 6.9 indicative of low organic matter, the finished waste had limited agricultural value, however, the treatment process *did* efficiently remove nitrogen in many samples and eliminate the pathogens in all of them.

Mean Specific Oxygen Uptake Rate (SOUR) values of 1.4 ± sd 1.1 mg O_2 / gram *total* solids were substantially close with the USEPA standard of 1.5. The SOUR on a volatile solids basis was not applicable. A socially and technically useful ASH/VS (inorganic/organic solids) ratio was discovered with mean concentration values of 6.8 ± sd 4.2 with most values falling within an easily explainable socially-valuable ten-point scale.

The introduction of two other dry batch composting toilets created a competitive situation in the community where comparative analysis was being performed with the preferred pour-flush water toilet. If water shortages continue, the desiccation toilet's acceptability may increase again.

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CHAPTER 1. INTRODUCTION

To completely comprehend the objectives of this report, an appreciation and realization is necessary of the efforts of the professionals and community members who participated in the sanitation project upon which this dissertation is based. A tremendous amount of engineering and anthropological field work was done on this project over two decades. The breadth and scope of this work is rare and unique. Over these two decades the technology and the project developed in unpredicted ways and directions.

The highly variable usage of the sanitation facilities resulted in a need for feedback to evaluate the initial acceptance and success, and the later rejection and failure, of many of these sanitation facilities and the project as a whole. "Has the introduced technology been accepted and successful in this community? If so, what were the contributing factors? If not, what went wrong? What factors contributed to the success or failure?" These were the burning questions at the heart of this endeavor. Changing sanitation habits is one of the most difficult changes for communities to make (Yacoob, Raddy, and Edwards, 1992). The attempt more often than not results in failure (Camp, Dresser, and McKee, 1983). The job of the social scientist (or anthropologist) is to "hold people's hands" in the difficult process of change (Jenkins, 2000).

The struggle to implement simple, low-cost, low-maintenance, culturally-appropriate sanitation technologies (often referred to as Appropriate Technology—AT) is at the center of this report. An effort on a global scale is on-going by many professionals and villagers involved in on-site community development sanitation projects to meet these basic needs. In remote areas of Mexico, Latin America and elsewhere, there is not sufficient potable water supply or adequate sanitation. As of circa 1980, there were two billion people without sufficient water supply and three billion people without adequate sanitation (World Bank, 1980) resulting in suffering from various illnesses and diseases and many other adverse impacts. In addition to improved health, there are many other benefits to community water and sanitation projects including education, economic, cultural, quality of life, and more (Okun, 1987).

Since 1988 in a village fictitiously named "Sonacala" in the lower highlands of central Mexico, a community development group and team had been working alongside members of that village in the implementation of a type of composting toilet, now being renamed as an alkaline desiccation compost toilet (see Figure 1.1). The team consisted of individuals from a Mexican government agency, a U.S. non-profit group, and local innovative technology promoters and practitioners. Since different levels of success had been seen and reported, and success itself had not been defined, the results from that project were unknown. The experience changed the awareness and perspectives of those involved from one based on theoretical constructs to one based on realities, practical experiences, and the limits and peculiarities of this community and of developing areas in general. That experience forced a reconsideration of assumptions made in regard to the sanitation technology, social factors, and community development. The model

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shown in Figure 1.1 is a brick-version of the alkaline desiccation compost toilet. Two other models of the alkaline desiccation compost toilet are the block version (see Figure 1.2) and the fiberglass version (see Figure 1.3). The brick and block versions (see Figure 1.4) are both double-vault toilets, with the only difference beside the material type being a slightly different toilet basin and seat. The fiberglass version is a single removable vault design.

After two years, 95 percent of the toilets were still being used. This high use rate was followed by a dramatic drop to approximately 10 to 30 percent after 14 years. The technical and social factors contributing to the limited success and limited acceptance are the major questions of interest in this report.

The technology has been entitled "alkaline desiccation environmental systems" because the investigated waste treatment system's basic functions involve controlling a desiccation process in a constructed system that relies upon high pH and alkalinity to accomplish its treatment objectives. This system of waste management, modifications, control, and analysis developed in this report for this particular application, and the associated moderately-rapid assessment technique, can both be used to develop or analyze other environmental systems, both natural and constructed ones.

One of the unique contributions this report has made is the very detailed analysis of the social acceptance and the analysis of the chemistry and physical processes of the desiccation-type toilet based upon actual, individual toilet case studies. This detailed analysis yielded some very firm, proven observations and results. It also brought to the surface some interesting and important issues that were not fully understood and accordingly not fully established scientifically. As a result, the reader is cautioned to distinguish appropriately between the two types of observations reported here. The unclear issues are areas for further investigation and validation.

Figure 1.1 Rearview of Brick Alkaline Desiccation Double-Vault Compost Toilet with vault doors drawn for demonstration (Photograph by Joel Roberts)

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Figure 1.2 Block Alkaline Desiccation Double-Vault Compost Toilet with Typical Stairs (Photograph by Armando Galvez)

Figure 1.3 Fiberglass Alkaline Desiccation Single-Vault Compost Toilet with Removable Vault (Front View) (Photograph by Armando Galvez)

Figure 1.4 Upgraded Potential Version of Brick Toilet, Twice the Average Cost. Atypical for Rural Area (located in Urban Area at Home of an Architect) (Photograph by Cesar Anorve)

CHAPTER 2. OBJECTIVES

There were three main objectives to the report—the principal ones being the evaluation of the technical adequacy of the facility and improvement of its design.

The principal objectives of this report were to determine:

1) the technical success or failure of the brick desiccation compost toilets and their indicators of success,
2) the adherence to operational and maintenance standards,
3) the satisfaction of practical physical (non-treatment) goals of the user,
4) the composting capacity and whether it can be considered a composting toilet at all, and
5) a preliminary determination of the acceptance and success of the block and fiberglass toilets

The overall technical success, or the technical failure, of the brick model of the desiccation bathrooms in the community was evaluated as shown below. Furthermore, a comparison was made to a limited number of the two other similar toilet types.

1) Satisfactory treatment was considered compliance with generally recognized scientific standards for sanitary waste treatment, including:
    a) Disease prevention (reduction of vector attraction and fecal coliforms),
    b) Pollution prevention of local water bodies and the general environment from decomposable organic matter, heavy metals, and excess nutrients, and
    c) Control of parameters affecting waste treatment and land application including pH, alkalinity, and moisture.
2) Operation and maintenance tasks that must be adhered to including detention time, additive use, proper batch operation, and removal and disposal of waste.
3) Finally, satisfaction of the practical goals of the user included:
    a) Comfort of use of the facility (i.e., the shelter), ambient temperature inside the shelter, insect control, odor, water-proofness, basin/seat comfort, and visual acceptability
    b) Convenience of use, adequate proximity for sake of convenience, adequate distance for other reasons
    c) Location and privacy.

The secondary objective of this report was to evaluate the social factors and acceptance of the toilets and participatory and implementation strategies.   The last objective was to analyze the rapid assessment technique by James Bebee (1995) and modify it for the technical and social challenges or factors in the introduction of the toilets based on the Sonacala experience.

CHAPTER 3. LITERATURE REVIEW AND ASSOCIATED REPORTS

3.1 Two-Step Approach

In international developmental sanitation projects, there are at least two basic components that must be addressed: 1) the technology that is chosen, constructed, and used; and 2) the program and its methodology and/or philosophy that assisted in the technology's selection, design, and implementation. These programs may have a health education or behavioral change component to them. Regardless of the approach, existing belief systems—in relation to health—need to be respected and/or incorporated into the sanitation activity and any posterior program evaluation. There are many indigenous health beliefs that may influence success and acceptance of interventions. In the design and implementation of interventions, some approaches use forward-looking scientific models while others use more community-based participatory approaches.

3.2 Existing Sanitation Technologies

The widespread, current, and preferred system in central Mexico appeared to be water-borne systems that required significant resources and various conditions to be built and used "properly." In urban areas, there was the conventional household bathroom with a ceramic toilet connected to a central sewer system, usually with or without limited or any treatment. The waste in this system was flushed by water that entered the toilet from a pressurized water line and discharged by gravity flow. In highly developed areas, this waste usually discharged through a very long, leak-prone, and expensive collection system to a very expensive central wastewater treatment plant, or to a nearby neighborhood package treatment plant, or home septic tank and system. In rural areas of Mexico, pour-flush toilets are more common. They consist of a conventional ceramic toilet basin and seat into which a bucket of water is poured to flush the waste (hence the title), however, the discharge pipe discharges either directly to a canal, a hole in the ground (cesspool), or usually at best a poorly designed one-stage septic tank without a drain field nor any aerobic treatment. In other locations throughout the world, aqua-privies are another common water-borne system. There are approximately seven basic on-site sanitation systems (Bates and Roy, 1984). Some of the above-mentioned required conditions for these waterborne sewerage systems are a large amount of capital funding, associated physical infrastructure, a municipal maintenance department and staff, an on-going, long-term financial budget, favorable hydro-geological and geographic characteristics, and the availability of tremendous amounts of piped water on a daily basis. None of these existed nor were available in Sonacala, as is the case in many areas in Mexico and around the world.

To overcome many of the above limitations of waterborne systems, traditionally the most common recommendation tended to be for very simplistic, dry, on-site facility types (i.e., pit latrines) that required little resources. The most complicated of the non-waterborne dry toilets is the Multrum Clivus Continuous Composting toilet. It is a continuous composting process, as opposed to the batch process used in the desiccation compost toilet. The literature and testing indicated that it was not a sustainable model in areas such as Sonacala, where a high level of infrastructure and maintenance support did not exist which was needed for its high operation and maintenance requirements costs. Parameters with this toilet that were difficult to control were the optimum moisture content, the carbon-nitrogen ratio, and the required oxygen. Food scraps and carbon material must be added to precisely control these parameters and a special slap was needed to achieve the continuous process. Other simpler options were Reed Odorless Earth Closets and bucket latrines, or other types of cartage systems. Unfortunately, those systems are often not favored by end users with the more modern-day western mentalities, because of the facilities' rustic nature, an associated social stigma, presence of odors and flies, the fear of falling in, the visibility of the waste, and other reasons. Many impoverished people appear to want to "progress" out of their poverty and, therefore, sometimes reject technologies that are further symbols and implements of that poverty, even though that technology otherwise may be a viable alternative.

Additionally, government agencies and environmental groups did not prefer the pit latrines because of the possibility of ground water pollution in areas with high water tables or highly permeable soils. There were regulations in a large municipality near Sonacala not allowing pit latrines. Only waterborne toilets were an approved system in that community. However, in Sonacala, there were no regulations governing wastewater disposal. Additionally, for the pit latrines, there were other practical problems such as difficult geological characteristics, that is, areas that are difficult to excavate and the high expense of blasting. Nonetheless, pit latrines were still used widely including the region near Sonacala, some implemented properly, some not. Although these often have significant odor and aesthetic issues, this technology is still used.

Regardless of the downfalls of other facility types, the criticism of the real problems of desiccation bathroom technology and its implementation is not to be taken lightly. Current information appears to indicate the desiccation bathroom should only be recommended where there is at least an "intermediate to high" level of support and resources, and high interest by end users motivating its selection, use, and maintenance. In summary, of the six most common on-site sanitation technologies, the pit latrine (the oldest option), the waterborne gravity or pour-flush toilets (the preferred and more-or-less new status quo), and the desiccation bathroom (the newest and least common) are the most predominant in this central Mexican area. They hold the most hope for combined social acceptance and technical success.

Now what is needed to further evaluate this technology is 1) an objective determination of the desiccation bathroom's success, 2) a straightforward analysis and determination of the influential technical and social parameters attributing to its success or failure, and 3) a realistic, meaningful presentation of the parameters, the techniques, and the results. This information, if presented properly to end users, could assist them in determining if they have the interest and adequate resources to implement more bathrooms, change to another model, maintain the existing ones, or even perhaps abandon them and return to their previous system. If this approach is successful, a similar type of approach to the investigation, documentation, and presentation of

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the other on-site sanitation systems would place all the on-site systems on a more level playing field. With all systems appropriately presented, end users could reasonably be expected to make informed choices based on realistic, consistently presented information, void of overly-aggressive promotional presentations that gloss over some of the challenges and weaknesses of each technology.

3.3 Missing Gaps and Associated Reports

In summary, the information and techniques that were lacking in the international on-site sanitation field are stated below and outlined in a series of reports that address the various components of this work:

1) An objective analysis and accounting of the success or failure of on-site sanitation systems, particularly compost toilets is needed. This in essence is a scorecard that assists in posterior evaluations in gauging a technologies success. This engineering analysis is covered in the body of this report.
2) The determination of social factors contributing to acceptance or rejection of on-site sanitation facilities, particularly desiccation bathrooms. This anthropological determination is covered in Appendix A through U, especially P.
3) The quantification of relative values of social and technical factors and development of a logical means to place weight, importance, and rank on factors in decision-making. This approach was demonstrated by Montgomery Watson Engineers (1999) in their sewer rehabilitation study in Baton Rouge, Louisiana, in which the author participated. The end product of this quantification of technical and social factors is presented in this report. That product included the elaboration of two tables (one technical, one social) for most of the 24 families studied for a total of approximately 36 tables.
4) A realistic, multi-disciplined, relatively simple approach to pre-project, on-going, and post-project program and technology evaluation is critical. A moderately-rapid decision support system is needed. The quantification step above is a required pre-cursor for use of this tool. The execution of the above tasks is required by multi-disciplined trained and experienced professionals using realistic engineering and anthropological techniques. .
5) The engineering field and laboratory procedures for the technical evaluation of desiccation compost toilets.

CHAPTER 4. METHODOLOGY AND PROJECT ANTECEDENTS

4.1 Project Antecedents

An opportunity existed in Sonacala, Mexico, to have a holistic analysis of both technical and social factors that influenced the successful and failed interventions of several organizations in the village's "development" or, better phrased, its path, initiatives, and choices. The objective of the team in their 14-year presence in the village was to provide alternatives and assist the members who chose to participate and solicited support. Sensitivity and incorporation of existing beliefs and behaviors related to health and sanitation was a part of the approach.

A lack of interest and financial support by funding agencies for these types of projects had prevented an analysis of the social factors (Camp, Dresser, and McKee, 1983), more than the technical ones. This was also true in the case of this particular village's sanitation project. As foundation funding decreased with a weaker U.S. economy, contributions to non-profit groups have also decreased. It appeared that at times only academia and its students had the interest, time, and resources to support, participate in on a long-term basis, and perform extensive evaluations of developmental projects.

Identification and development of such information by personnel with both technical and social backgrounds using the above three vantage points (engineering, anthropology, and a combined approach) had not been funded and appeared not to exist, which is true in the case of this central Mexican village. Particularly lacking was an intensive objective investigation of a long-term in-place sanitation project with desiccation bathrooms in central Mexico. The desiccation compost toilet is a new technology whose parent technology was invented in Vietnam in 1959 and later modified and introduced in Latin America. Other work had been done in Sonacala, but investigators were only present in the community for short time spans, and thus could not have a deep understanding of the community. One group was a governmental agency most probably with a top-down, traditional bureaucratic approach. There were two other organizations that intervened in the community—one an environmentally-based group that was a proponent of innovation of appropriate technology that actively promotes desiccation bathrooms and the other a business whose motives were assumed to be strictly financial since it manufactured a later fiberglass version of the introduced technology that was purchased and installed by the municipality for a price substantially higher than the cost to build and install the other two versions. The opinions and promotions coming from these two groups may have resulted in biased information that needs to be reevaluated objectively. This biased information and attitude may have projected a view of the reportedly environmentally-friendly toilets more favorable than the reality of their implementation, use, maintenance, and state of hygiene. On the other hand, developmental planners and others may have an inappropriately exaggerated, pessimistic view of the potential feasibility of desiccation bathrooms. Regardless, this view appears to be based on real failures to date of desiccation bathrooms in areas where adequate

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resources and appropriate implementation techniques were not available for their long-term sustainability. Still yet, other sanitation options generally favored (besides desiccation and compost toilets) have difficulties and failures also. The pros and cons continue. Accordingly, because of the wide disagreement on the on-site technologies' sustainability, consensus-building is needed. It must be accomplished with a well-rounded "peer group" to evaluate the results and establish "the truth" and the standards.

4.2 Investigation Team

The investigation team (see Figures 4.1 and 4.2) was comprised of four members, one each from the following four areas: Mexican health department "health promoter," local agronomist and supplier of toilet parts, sanitation engineer, and a non-specialized worker.

The Mexican health promoter and the sanitation engineer helped each other to overcome their limitations and forged an intense partnership dedicated to assist the community in appropriate ways and with appropriate techniques. They became "joined at the hip" and rarely left each others' side while in the community. The engineer depended on the promoter's tremendously advanced listening skills and the promoter was open and directed by the engineer's creative, imaginative skills.

The agronomist/desiccation toilet part supplier provided technical help. He had a preference for the desiccation model, as did his architectural brother who was a well-known innovator of appropriate technology and who had ties to or followed the guidance of such Mexican thinkers as Gustavo Esteva, Ivan Illich, and the French writer Jean Robert. Although desiccation bathrooms were their preference, if not sole choice of sanitation technology, they was sensitive to villagers' wishes to participate or not. They were intuitive and compassionate. They earned part of their livelihood from the sale of desiccation toilet basins that they manufactured and designed and innovated with a Mexican university. They had a tendency for the promotion of environmental values. Even with these facts, they followed the philosophy of the program's approach of participation by invitation only and did not coerce or force their values on community members. Also, he had limited frontline work with the community and had a very non-aggressive personality style. Last of all, there was little known about the non-specialized worker. He was selected by the desiccation toilet promoter and was only present in the community for a two-week period during sampling. He had a slightly aggressive style but was very jovial and had a great skill of lightening the atmosphere with a joking style and charismatic way, using a good smile and laughter which relaxed villagers. During one interview, he and the sanitation engineer were rightly accused of "rapid fire" questioning of one community member. After that slap on the wrist, they both are believed to have made a communication style adjustment. Overall, the team appeared to meet the criteria of multiple team members, according to the approach of Bebee (1995), the author of the rapid assessment technique discussed further below.

Figure 4.1 Solvita® Tests and Seed Germination Trials Being Conducted (Photograph by Joel Roberts)

Figure 4.2 The Sonacala, Mexico, Investigation Team: Left to Right: Armando Galvez, Joel Roberts, and Benito Gutierrez (Photograph by Israel Monroy–additional team member)

4.3 Engineering and Other Procedures

The principal procedures and standards used in this project for the collection, field analysis, transport, and laboratory analysis of the desiccated compost samples were derived from the following references:

1) *Standard Methods for the Examination of Water and Wastewater Treatment*, American Public Health Association (2007).
2) *Procedures for Analysis of Compost*, Callegari Environmental Center (2002).
3) *Guide to Solvita® Testing for Compost Maturity Index*, Woods End Research (2000).
4) *Evaluating Compost Quality*, U.S. Composting Council (2008),
5) *Alternative Graphical Forms of Presenting Technical Information*, Cesar Anorve (1988).

For clarity, procedures have been incorporated directly into various sections of the remaining sections of this report.

Various photos, drawings, and *cartoon-like* illustrations have been provided in the body and appendices of this report that represent graphically procedures for disseminating information, educating users, and providing design and construction specifications. These graphical procedures have been created by a local Mexican architect and innovator, Cesar Anorve. More information about his procedures can be found in the Appendices and also have been incorporated into the body of the report. His brother, Israel Monroy, manufactures needed parts and appurtenances for the desiccation toilets. These parts are actually used by users in rural and urban areas.

Figure 4.3 Parts and Appurtenances manufactured by Israel Monroy and designed by Cesar Anorve (Photograph by Cesar Anorve)

CHAPTER 5. DESICCATION SYSTEM OPERATION

5.1 Waterborne and Dry Sanitation Systems

Human excrement collected through conventional wastewater systems is in a liquid state—the matrix is water. A two-step nitrification treatment process can occur, involving oxygen, and may be followed by a denitrification step in the presence of carbon, converting the nitrogen compounds to nitrogen gas. A summary of these equations is provided further below.

The desiccation compost bathroom is a non-waterborne sanitation system that separates the excrement from the urine, and does not use water, thus establishing its operation in a dry mode. The waste vaults and shelter are built above natural ground level (see Figures 5.1 through 5.3). The absorption pit, where the urine is discharged to, is excavated in the ground adjacent to the vaults. For the brick and block desiccation toilets, they operate in a two-part batch-type operation as described below. The fiberglass toilet operates with only one chamber that has a removable fiberglass bin in place; modifications to the batch operation below for single-batch process for the fiberglass toilet is shown in brackets below.

5.2 Operation

1) The excrement is introduced by gravity into the vault (since the toilet basin and seat where the user sits are directly above the vault in use).
2) Through a urinal that is built into the seat (that is comfortable and manageable by both men and women) the urine is kept separate from the excrement and by its discharge into the urinal, which is connected to a ¾" hose, discharges to the absorption pit, which usually consists of gravel and sand. There are also some toilets that have stand-up urinals for men that also discharge to the absorption pit. No water or any liquid can be introduced to vaults, not even small amounts for any cleaning purposes. However, the urinal can be cleaned with water.
3) After every use, it is necessary to introduce an additive. Commonly used is either soil, sand, ash, and/or lime (sand is the least desirable additive).
4) The first vault <or fiberglass bin> is allowed to fill ¾ of the height which results in a detention time (T_1).
5) Periodically the waste pile, which forms in the shape of a cone, should be leveled and mixed, usually with a rod, stick, or hoe from the toilet basin opening for the brick and block models <this method can also be used for the fiberglass bin, or it can be removed from the chamber, mixed, and leveled, and re-inserted back into the chamber>.
6) The hole in the shelter floor underneath the toilet basin must be closed off with a tight-fit lid, usually a concrete plug and maybe mortar <not necessary for fiberglass toilets>.
7) The remaining top one-fourth of the vault <or bin> should be filled with soil, or if not available, sand.

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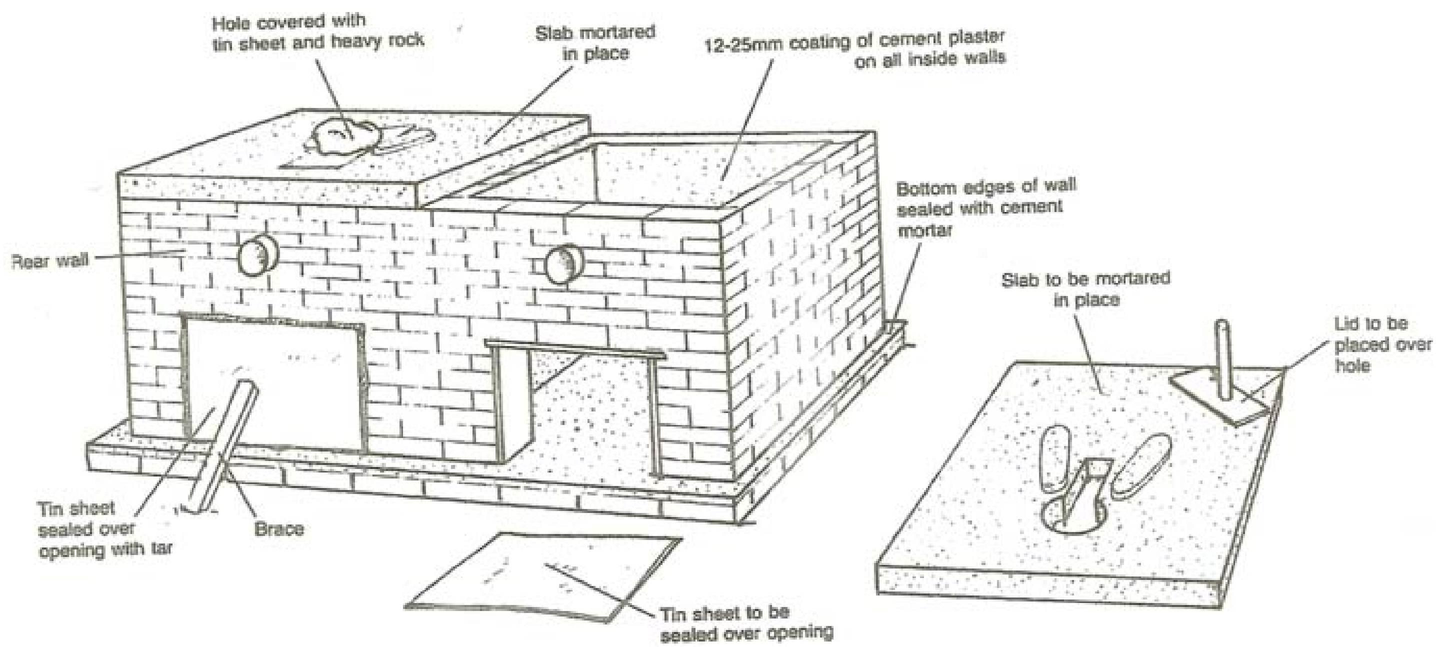

Figure 5.1 Compost Toilet Vault Under Construction (Squat Model) (Drawing from Water and Sanitation for Health Project conducted by Camp, Dresser, and McKee)

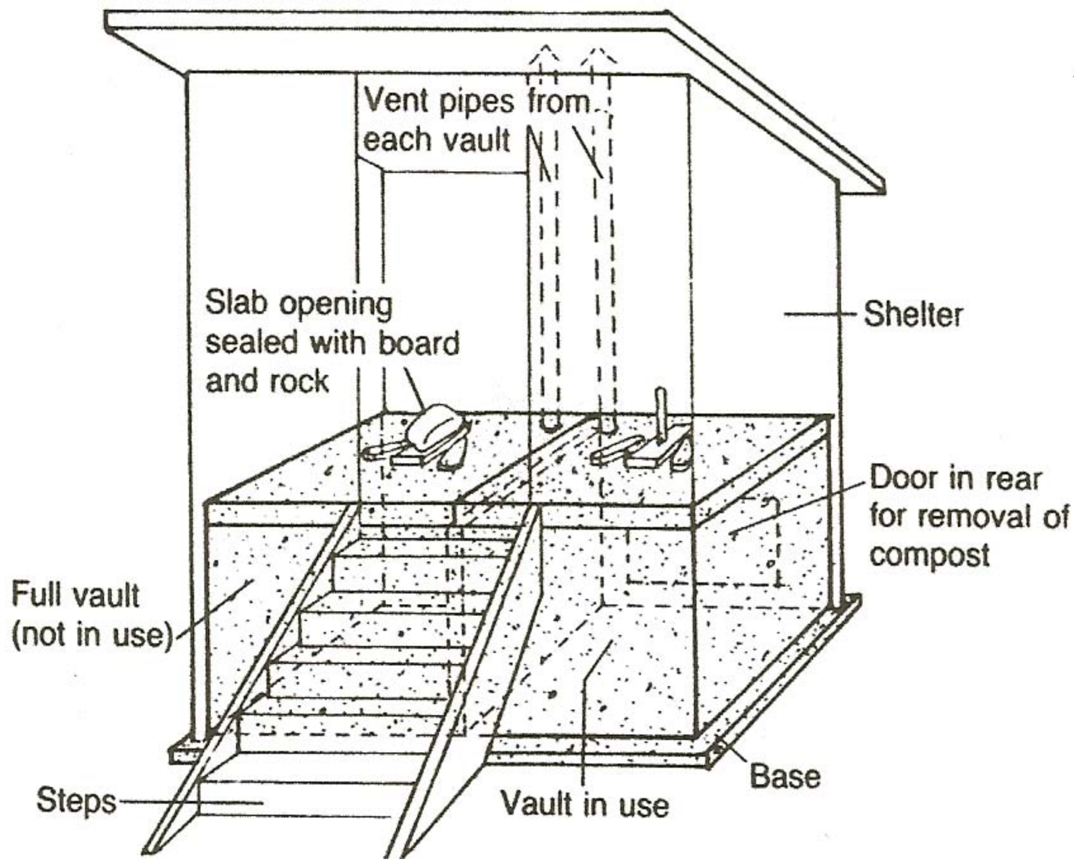

Figure 5.2 Compost Toilet 3-Dimensional View of Shelter and Vaults (Drawing obtained from Water and Sanitation for Health Project conducted by Camp, Dresser, and McKee)

8) The first vault <or fiberglass bin> should remain in repose, preferably a minimum of six months and a maximum of 12 months (for project management reasons). (The current design of each vault's volume of approximately 1.0 cubic meter, with dimensions of approximately 1.0 meter wide by 1.0 meter deep and 1.0 meter high, has resulted in much greater than the one-year repose time for the brick and block toilets.) It is recommended that a repose time no longer than 12 months be used <for the fiberglass toilets since the repose time could be less than six months, multiple containers must be available so that the waste can receive further treatment outside of the toilet>.
9) The second vault is used <not applicable for fiberglass bin>, additive introduced, mixing performed and allowed to fill, resulting in a detention time, T_2. Note that the treatment time of the last waste introduced into the first vault is equal to T_2. The treatment time of the last waste introduced into the second vault will be equal to T_3, the fill time of the first vault in its second cycle.

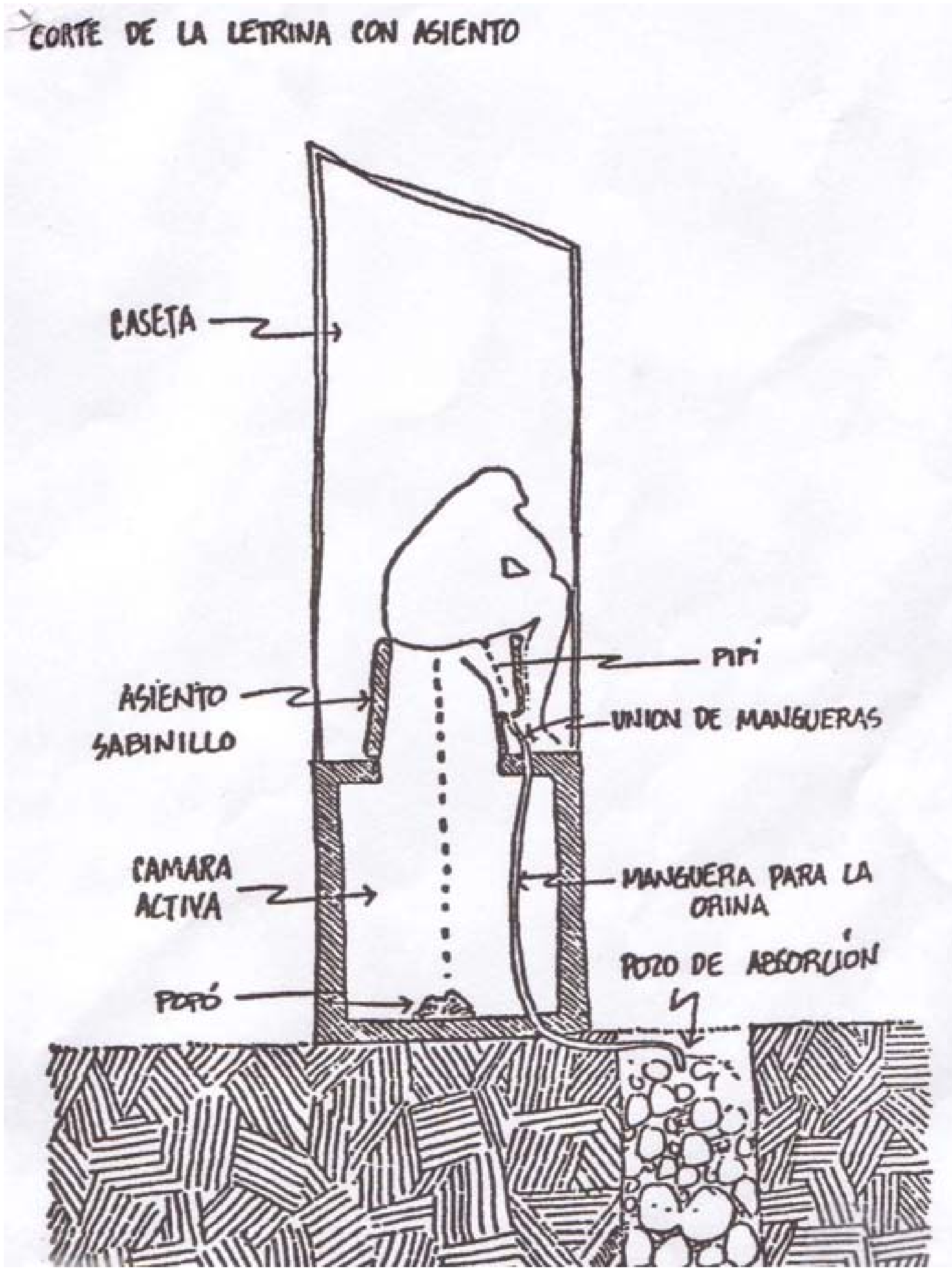

Figure 5.3 Compost Toilet Side View of Use Method with Toilet Basin and Built-In Urinal (Drawing by Cesar Anorve, Centro de Investigacion de Tecnologia Alternativa (CITA))

10) For the brick and block toilets, the contents of the first vault is removed (with considerable effort and some close contact with the waste) from a small trap door usually 12”x12” or 18”x18” on the exterior of the vault’s back wall. The contents are used as fertilizer, fill, or as mix to re-introduce to the toilet, or are disposed of or treated further outside the vault. This ends the first complete cycle for the brick and block toilet. <For fiberglass toilets, its removable fiberglass bin is easily removed and placed on site at a location secure from animals and a lid possibly placed on top. Since detention time is usually a minimum of three months (usually maximum of six months) a third and fourth bin may be necessary. The third and fourth bins are operated in a similar manner. All bins should be tracked to ensure 12 months of treatment. <It is very possible, if the toilet was operated well, to remove the waste after six months in the bin and place in a secure compost pile for another six months for the remainder of the 12-month repose time. This may even facilitate decomposition and result in a better compost since some re-introduction of oxygen could occur due to surface diffusion and/or mixing.>
11) The first vault’s use is re-initiated, starting the second cycle <a second fiberglass bin is inserted in the toilet>.

In brief, the process for the brick and block toilets can be summarized as follow:

1) First vault used for 12 months, additive introduced, mixing done, topped with soil and vault sealed.
2) Toilet basin moved on top of second vault and operated in the same manner for 12 months.
3) First vault’s contents removed, used, placed in compost pile, or disposed of in adequately-thin land application, basin moved and its use reinitiated.

The process for the fiberglass toilet can be summarized as follows:

1) Single chamber toilet used for three to six months, additive introduced, mixing done, bin removed, pile can be turned, and bin placed on-site, then topped with soil, possibly sealed and secured from animals.
2) Second bin placed in chamber and operated in same manner for three to six months.
3) Contents of first bin (located on site) removed after total repose time of 12 months, used, placed in compost pile, or disposed of by adequately-thin land application.
4) A third and fourth bin may be used, ensuring all bins have a minimum of six months’ repose time in bin and another six months in a compost pile.

CHAPTER 6. TREATMENT PROCESS

6.1 Chemistry of Calcium Oxide (Quicklime)

Human waste consists of water and organic matter and includes complex molecules of carbohydrates and ammonium. Ammonium is the most critical component that needs to be treated, along with the pathogens that exist within it and that can be introduced into it from insects and rodents that may be in contact with it. The desiccation bathroom's most apparent treatment process of the ammonium is a chemical process using a form of lime.

Calcium and magnesium are the two basic components of some lime products. The chemistry of calcium and magnesium is very similar. Calcium and magnesium, group 2 metals, have a valence of 2+ thus the chemical formula for the metal ion is M^{2+}. The metal ions, in aqueous solution, combine with other ions such as oxide O^{2-}, hydroxide OH-, carbonate $CO3^{2-}$, hydrogencarbonate HCO_3^-, chloride Cl^-, sulphate SO_4^{2-}, nitrate $NO3^-$, to form a calcium or magnesium compound. The chemical formula for calcium oxide is CaO, calcium hydroxide is $Ca(OH)_2$, calcium carbonate is $CaCO_3$, calcium hydrogencarbonate is $Ca(HCO_3)^2$, calcium chloride is $CaCl_2$, calcium sulfphate $CaSO_4$, and calcium nitrate is $Ca(NO_3)_{2.}$ Magnesium and calcium oxides or hydroxides are slightly soluble in water, forming alkaline solutions. The oxides and hydroxides readily react with acids to form salts—chloride salt NaCl2, nitrate salt $Na(NO_3)_2$, and sulphate salt, $NaSO_{4\ (aq/s)}$. The sulphate of calcium is not very soluble and this slows the reaction down and calcium hydrogencarbonate are soluble in water and cause "hardness," that is, scum with "traditional" non-detergent soaps, $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$ (Brown, 2007). Of these compounds, calcium oxide and calcium hydroxide (and the magnesium equivalents), with their partial solubility in water, are the most pertinent to the desiccation toilets' treatment process.

Limestone rock ($CaCO_3$), calcium carbonate, can be crushed to form limestone powder. Alternately, if limestone rock is heated at 900 degrees Celsius, it is converted into calcium oxide (CaO), commonly known as quicklime, the common form of lime used in construction, agriculture, and in particular as the additive in the desiccation toilet (see Equation 1). A second component in quicklime is magnesium oxide, MgO, whose chemical reaction is similar to the one shown for calcium oxide.

$$\underset{\text{(calcium carbonate)}}{CaCO_3} \xrightarrow[900^o\,C]{} \underset{\text{(quicklime)}}{CaO + CO_2} \qquad \text{Equation 1}$$

The chemical treatment process in the desiccation toilet is a four-part alkaline desiccation process. When quicklime is placed in water or comes in contact with moisture in solids (as in the desiccation bathroom), it reacts with the water to form the calcium derivatives of solid calcium hydroxide, commonly known as slaked lime (see Equation 2) (Brown, 2007). This is part of a process known as the lime cycle.

CaO + nH_2O → Calcium Derivatives(s) Equation 2
(calcium oxide)

This conversion of calcium oxide and water into calcium hydroxide ($CaOH_2$) (see Equation 3) is the first process that removes water from the waste. This reaction between water and quicklime is a very exothermic reaction (produces a lot of heat). In this conversion process, the quicklime "puffs up" and steam is released (Brown, 2007). Accordingly, evaporation of water directly from the waste material through increased local temperature is the second process that removes water from the waste.

CaO + 2 (H_2O) → $Ca(OH)_2$ + H_2O Equation 3
(calcium hydroxide)
(in prescense of strong cation)

In the resulting products of the reaction of Equation 3, at a superficial glance, it is not clear what the mechanism is that increases the pH of the solution, since there is no hydroxide molecule that is evident in the products of the equation on the right hand side, as it is written.

However, the two hydroxide molecules in the calcium hydroxide (and the one hydroxide in the water molecule), in their ionic state in solution in which they exist, do become available by an attraction process at the ionic level, thus increasing the "effectively available OH^-" and the "effective pH" that produce the desired alkaline environment. A brief explanation follows.

6.2 Mechanism and Chemistry of pH Increase in the Waste

Water is polar (see Figure 6.1). The force of the hydroxide molecule can and does pull protons away from other compounds that are in solution with the water. Ammonium, an acid (acid being defined to be a hydrogen donor), being weak, does not readily donate the hydrogen ion, however the hydroxide molecule, a strong base, strongly attracts the proton (the hydrogen molecule) from the ammonium (Prey, 2008).

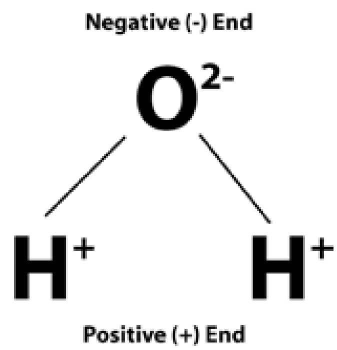

Figure 6.1 Polar Nature of Water (Illustration by Kurt Prey)

In the case of the desiccation toilet, calcium hydroxide (see Figure 6.2) in the human waste in the toilet vault *does* exist in an “inter-granular” or “inter-molecular” aqueous environment. The environment (the soil matrix) at this level, at the inter-granular level, is an aqueous environment because in only one mole of a substance (water and calcium hydroxide in this case) there are 6 x 10^{23} molecules! The mixed vault materials (the waste) with its internally-bound water that naturally occurs in the material (a mix of human wet excreta, soil, ash, and lime), had water content values of 5 to 20 percent at the time of removal from the vaults.

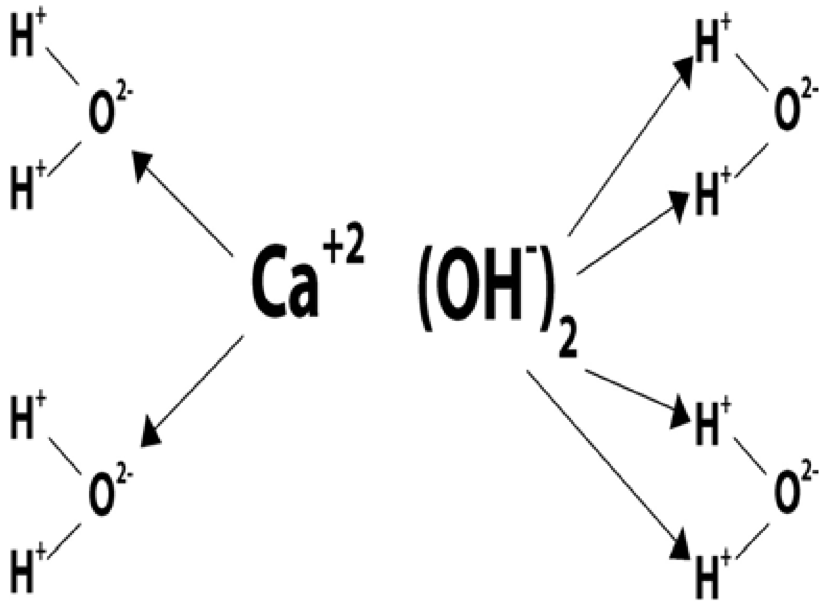

Figure 6.2 Attraction of Calcium Hydroxide Ions to Polar Sides of Water (Illustration by Kurt Prey)

The quick lime, as noted above, once reacting with water, produces calcium hydroxide. The hydroxides of these calcium hydroxide molecules, being in solution at the inter-granular level, become available. These hydroxides are the hydroxides that react with the ammonium in Equation 7 below, thus creating ammonia.

The ammonia (ammonium) can exist in both solid and gaseous forms. The gaseous form is the form released to the atmosphere—which is the desired reaction from the pollution prevention standpoint. If there is an acidic environment (an excess of hydrogen ions), the ammonium that remains in the solid form (kept in solid form by the acidic, low pH environment) continues to exist in the waste after it is removed from the toilet’s vault.

The detail of the particular reaction that occurs is not of great significance in this work. The highly significant characteristic of calcium oxide is that it does create a highly alkaline environment, up to a pH of 11.5. This high pH environment also serves to reduce the number of pathogenic organisms. Most pathogens cannot survive at higher pH levels (Redlinger et. al., 2001).

6.3 Odor Reduction

The fourth treatment process occurring as a result of this alkaline environment is odor reduction. With an alkaline state maintained long enough and homogenously throughout the pile, the ammonium (a solid) is converting to ammonia (a gas). If all the pathogens have been eliminated and all of the ammonium is converted into ammonia and released into the atmosphere and the moisture has dissipated, the treatment process is basically complete. If there is complete removal of ammonia, the only substance left is the inert soil matrix, which held the excrement initially. This matrix can be almost, if not all, sand and silt like fine particles, which can be used as an excellent additive for the next cycle.

Another possible treatment process that could be necessary is neutralization of any waste with unacceptably high pH or alkalinity. Finally, it should be noted that complete elimination of all ammonium is not necessary, since this is a valuable component of fertilizer. The microbes can be reduced adequately and still allow some remaining ammonium for agricultural purposes. This issue is covered further below.

6.4 Treatment of Ammonium

Human waste in its natural state consists of organic nitrogen (a solid) and urea (a liquid). In waterborne systems, the waste is mixed with water. In the desiccation toilet, the only water present is that which is in the waste. Under certain conditions, the organic nitrogen can be broken down to ammonium (NH_4^+) or ammonia (NH_3) (see Equation 4). The pH of the waste and the surrounding environment causes this nitrogen compound to fluctuate back and forth, as the pH changes (see Equations 5 and 7). In the desiccation toilet, through addition of lime and ash <Equation 6>, the pH is raised which converts ammonium, NH_4^+ (an unstable compound) to ammonia, NH_3 (a gas) <Equation 7> causing some the associated ammoniacal odors to be released. The odors travel through a respiration pipe and through the oval opening in the floor under the toilet basin/seat and then from the toilet basin into the shelter. The increased pH of the waste “drives off” the odors.

$$\text{Organic Nitrogen + Urea} \rightarrow \underset{\text{Ammonium (Ammonia)}}{NH_4^+ \quad (NH3)} \qquad \text{Equation 4}$$

$$\underset{\text{(Ammonia)}}{NH_3} + H_2O \rightarrow \underset{\text{(Ammonium)}}{NH_4^+} + OH^- \qquad \text{Equation 5}$$

(Acidic Environment - low pH)
Low pH (acidic) drives equation right

$$CaO + 2\,H_2O \rightarrow (\,Ca^{2+},\ OH^-,\ OH^-\,) + H_2O \qquad \text{Equation 6}$$

(Creates Alkaline Environment – high pH) (Heat produced also)

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NH_4^+ + OH^- → NH_3 + H_2O (Reversible) Equation 7
(Ammonium) (Ammonia) dependent on pH

(Alkaline Environment – high pH)
High pH drives equation right (pH > ± 9–11) / drives off NH_3

6.5 Nitrification and Elimination of Denitrification as a Process

If there is any remaining ammonium (solid) it needs to be broken down further, or untreated it would remain locked up, as a solid, in the soil matrix and have the potential to pollute downstream surface waters or groundwater. Under the proper conditions, the excrement can be broken down from ammonium all the way to nitrogen gas. It is believed that those conditions do not exist, during most of the retention time of the waste in the desiccation bathroom, in particular due to the absence of adequate oxygen, water, microbial organisms, and the presence of an alkaline environment adverse to the microbial organisms. For the sake of further eliminating these nitrogen removal processes as potential processes in the desiccation toilet, they are further described below.

If there is adequate oxygen, moisture, proper pH, and microbial organisms, the below aerobic processes (called a nutrient removal process) could occur, converting the nitrogen compounds in several stages of nitrification as shown in Equations 8 through 11. Nitrification is an autotrophic process (i.e., energy for bacterial growth is derived by the oxidation of nitrogen compounds, primarily ammonia) (Tchobanoglous and Burton, 1991). Ammonia is found in solution with ammonium, or as a gas, is released.

The first stage of nitrification(part of composting) which converts ammonium (NH_4^+) and/or ammonia (NH_3) to Nitrite (NO_2) in the prescense of *Nitrosomonas* microbes is:

Organic Nitrogen + Urea → NH_4^+ (NH_3) Equation 8

NH_4^+ + 3/2 O_2 + *Nitrosomonas* bacteria → NO_2^- + $2H^+$ + H_2O Equation 9
(Nitrite)

The second stage of nitrification converts NO_2^- (Nitrite) to nitrate (NO_3^-) in the presence of *Nitrobacter* microbes:

NO_2^- + ½ O_2 + *Nitrobacter* → NO_3^- Equation 10
(Nitrite) (Nitrate)

To remove this nitrate, several different steps are required and are shown below. The process is simplified below into a single step, Equation 11.

The removal of nitrogen in the form of nitrate by conversion to nitrogen gas can be accomplished biologically under "anoxic" (without oxygen) conditions. This process is known as denitrification. In the past, the conversion process was often identified as anaerobic denitrification, however the principal processes are not anaerobic but rather a modification of aerobic pathways. Conversion of nitrate nitrogen to a readily removable form can be accomplished by several genera of bacteria in a two step process. The first step is conversion of nitrate to nitrite. This stage is followed by production of nitric oxide, nitrous oxide, and nitrogen gas. The last three compounds are gaseous products that can be released into the atmosphere. The reactions for nitrate reduction are shown below (Tchobanoglous and Burton, 1991).

$$NO_3^- + \text{Carbon} + \text{bacteria} \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2 \qquad \text{Equation 11}$$

The above process is called denitrification because all the nitrogen is converted to gaseous nitrogen products and can be released to the atmosphere. In denitrifying systems, dissolved oxygen (DO) concentration is the critical parameter. The presence of DO will suppress the enzyme system needed for denitrification. Alkalinity is produced during the conversion of nitrate to nitrogen gas resulting in an increase in pH. The optimal pH lies between 7 and 8 with different optimums for different bacterial populations. Temperature affects the removal rate of nitrate and the microbial growth rate. The organisms are sensitive to changes in temperature (Tchobanoglous and Burton, 1991). From the above review, it does not appear that the above processes could be present in the desiccation toilet, except perhaps minutely initially or under poorly operated conditions. These processes typically only occur in human waste that is in the liquid state. Other processes used to treat non-liquid waste were considered as possible explanations of the processes in the desiccation toilet. Considered was anaerobic digestion of municipal sludges—a conventional process to treat human waste in the semi-solid state. It will be shown that it appears that neither does that process occur in the desiccation toilet, at least not significant.

6.6 Elimination of Anaerobic Digestion as a Significant Process

Anaerobic digestion is one of the oldest processes used for the stabilization of sludges (wastewater with a limited concentration of water). It involves the decomposition of organic and inorganic matter in the absence of molecular oxygen to a variety of end products including methane (CH_4) and carbon dioxide. In treatment plants, sludges are thought to occur in three steps: 1) hydrolysis, 2) acidogensis, and 3) methanogensis, which involve the bacterial conversion of the intermediate compounds (from the first two steps) into simpler end products, principally methane and carbon dioxide. In a (municipal) digestor, a consortium of anaerobic organisms work together to bring about the conversion of organic sludges and wastes including the first group for hydrolysis, a second anaerobic group of bacteria, consisting of facultative and obligate anaerobic bacteria (collectively identified as “acidogens” or “acid formers”), and a third group of microorganisms, which are strict anaerobes and are called methanogenic, and are identified as “methanogens,” or “methane formers,” most of which have very slow growth rates.

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To maintain this system the bacteria must be in a state of dynamic equilibrium. To establish and maintain such a state, the reactor contents should be void of dissolved oxygen and free from inhibitory concentrations of such constituents as heavy metals and sulfides. Also, the pH of the aqueous environment should range from 6.6 to 7.6. A sufficient amount of nutrients, such as nitrogen and phosphorus, must also be available to ensure the proper growth of the biological community. Growth factors may also be required and optimum temperature ranges are the mesophilic, 85 to 100 degrees F (30 to 38 degrees C), and the thermophilic, 120 to 135 degrees F (49 to 57 degrees C) (Tchobanoglous and Burton, 1991).

It will be shown that the conditions necessary for this anaerobic digestion to occur in the desiccation toilet do not exist, primarily that the waste must be in an aqueous solution (a water matrix)—the very opposite concept of this dry toilet, whose waste is by definition in a soil matrix. Furthermore, even if the vault got wet (which sometimes does occur due to poor operation), the other necessary conditions that are not present include an environment void of dissolved oxygen, a more acidic environment, adequate nutrients, and preferred high temperatures.

6.7 Principal Treatment Processes Summary

Having eliminated the above aerobic and anaerobic biological processes, the only other processes that remain are physical and chemical treatment processes. The lime desiccation process is both a chemical process (alkalinazation) and a physical process (desiccation). These were the only significant processes that were successfully isolated as explanations of the treatment processes in the toilet in question. In summary it was shown below that there were seven principal processes that resulted from the lime treatment of the waste that occured in the desiccation toilet. In Step 1 during the first period of the fill time where adequate water content and favorable pH's could have existed, microbiological decomposition may have occurred. Steps 2, 3 and 4 were desiccation steps. The fifth step was a disinfection step. The six step was odor reduction treatment, and the final seventh part, was an environmental protection step. They are summarized as follows:

1) Loss of organic matter (and possibly ammonium) by conversion to dead, stable microbial organism shells and excreted matter.
2) Through the supply of external heat to the waste from the environment (i.e., heat in the air and in vault wall surfaces) to physically evaporate water from the waste.
3) Conversion of quicklime CaO and water (H_2O) to calcium hydroxide $Ca(OH)_2$ thus loss of water.
4) Removal of the water due to the heat released by the reaction above (in step 3) evaporating the water in the waste.
5) Production of hydroxide molecules (OH^-) in step 3. These hydroxide molecules create a high pH environment which eliminate pathogenic microbes and create an environment unsuitable for others to grow.
6) With the same hydroxide molecules above (step 3), these molecules react with ammonium (a solid with a strong odor) to release ammonia (a gas having a strong odor),

thus eliminating highly undesirable odors which escape into the atmosphere (the odor reduction step).

7) As a result of the same process in step 6 above, if there is sufficient lime and mixing, a lot of the ammonium is believed to be converted to ammonia's gaseous form. These nitrogen compounds have a potential to consume oxygen in receiving streams. Having thus been eliminated, one aspect of the oxygen consumption potential of the waste prevents eutrophication, a process that produces fish kills, general water quality reduction, and other negative impacts to aquatic life, including reduction in the recreational value of the water body (remaining non-nitrogenous forms of organic matter continues as a potential oxygen demand).

As mentioned above, the other processes not believed to be significant treatment processes in the desiccation toilet were aerobic nitrification and anoxic denitrification, anaerobic digestion, and composting processes.

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CHAPTER 7. FIELD, LABORATORY, AND OTHER DATA ANALYSIS AND DISCUSSION

7.1 Influential Parameters

Some of the surrounding environmental conditions are hydrogeology and climate. The analytical parameters that are influential in conventional nutrient removal biological growth processes (such as nitrification and anaerobic digestion), composting, and also influential in desiccation treatment process are pH, alkalinity, temperature, external forms of light, detention time (or period of repose), and various forms and occurrences of water.

External sources of light were direct sunlight and indirect sunlight in shady areas. Water occurred in various forms including the interior water content of the waste, water vapor released from the waste, water condensated on inside vault surfaces, moisture present on the outside surface of the vault, ambient humidity (water content in air), rainfall, and stormwater runoff. The Spanish term "humedad" (direct translation—humidity) was a term used in one literary source from Guatemala (Xet, 1988), that was used synonymously with the water content of the waste. In this report, the term water content (not humidity), is used to refer to the internally-held water inside the waste. The term moisture is sometimes also used synonymously with water content, particularly by the reporting from the Callegari Environmental Center (2003).

Indicators of the level of waste treatment are fecal coliform and other microbes; oxygen demand, as measured by the specific oxygen uptake rate parameter (SOUR); Solvita® maturity index, as an indicator of nitrogen, including ammonium, carbon, and to a lesser degree inherent oxygen demand; volatile solids reduction; organic matter reduction; and heavy metals. Parameters of agricultural value analyzed were macro-nutrients of phosphorus, potassium, and nitrogen (PKN), and carbon/nitrogen (C/N) ratios. Resulting possible adverse conditions, parameters of most impact on the user, are insect proliferation, disease transmission, and odor. Following the below explanation of the sampling approach, these conditions and parameters are presented and discussed. Complementary data was found and analyzed from other projects involving desiccation toilets in order to question or validate the data of this project.

The key operation and maintenance (O&M) tasks for the desiccation bathrooms are as follows: 1) Introduction of Additive/Cover Material, 2) Leveling, 3) Vault Switching, 4) Waste Removal, Disposal, or Use, 5) Maintenance of Toilet Basin Aesthetics, and 6) Maintenance of Urinal and Discharge Hose. Above was a description of the chemistry of the quicklime used in the O&M process and its interaction with the ammonium in the waste. The analytical parameters are discussed in detail below and the influence that they have on the decomposition of the waste as the O&M process proceeds. These O&M processes, particularly use of the additive, mixing, and leveling have been shown to dramatically influence the chemistry and the treatment.

One of the unique contributions that this report has made is the very detailed analysis of the social acceptance and the analysis of the chemistry and physical processes of the desiccation-type toilet based upon actual, individual toilet case studies. This detailed analysis yielded some very firm, proven observations and results. It also brought to the surface some interesting and important issues that were not fully understood and accordingly not fully established scientifically. As a result, the reader is cautioned to discern appropriately the two types of observations reported here. These important issues are areas for further investigation and validation.

7.1.1 Sampling Regime and Data

The sampling regime and data for the toilet types are discussed below. The breakdown of the toilet types by family along with reported detention times are shown below in Table 7.1. A summary of the pertinent sample data results by toilet is shown in Table 7.2. Means, standard deviations, and allowable limits for pertinent data are shown in Table 7.3.

7.1.2 Brick Toilet Samples

Samples were withdrawn from the available brick desiccation toilets that were already in repose. From the five brick toilets available (4, 7, 8, 22, and 24), one sample was collected from the top and one from the bottom half of the vault in repose, for a total of ten samples. Samples labeled “A” in Table 7.2 were taken from the top half of the vaults in repose and those labeled “B” were from the bottom half of the same vaults in repose. Sub-samples from each half were withdrawn, then they were homogeneously mixed to form one composite sample.

7.1.3 Block Toilet Samples

Family 11 had both a block toilet and a fiberglass toilet. This was the only block toilet that was available and had a vault in repose that was sufficiently advance to be considered representative of a finished (treated) waste. Samples from the block toilet were collected for the top and bottom halves and labeled 11a (top half) and 11b (bottom half). The sample from the fiberglass toilet at Family 11 was designated 11c. The quality of the samples from the toilets at Family 11 were of concern.

After the samples were composited for the top half of Toilet 11a, the sample was divided equally and submitted to the laboratory for analysis as a cursory check on the accuracy of the testing procedures (since these findings were not consistent and not analyzed statistically, they have not been discussed further). For reporting purposes, the two samples were arithmetically averaged and used in comparison with the one sample taken from the bottom of the same vault.

7.1.4 Fiberglass Toilet Samples and Soil Samples

Two fiberglass toilets were sampled at the sites of Family 11 and 13. Three soil samples (numbers 25, 26, and 27) were collected from ground surfaces around the community that were

Table 7.1
Desiccation Toilets by Type and Actual Detention Times (Sonacala)

BRICK		FIBERGLASS		BLOCK		WATER	
Toilet #	Detention Time (years)	Toilet #	Detention Time (years)	Toilet #	Detention Time (years)	Toilet #	Detention Time (years)
8	3	13	.25	16	.5	24	
21	3	2	1	17	.5	5	
24	3	5	1	18	.5	22	
4	4	13	3	20	.5	12	
10	5	1	?	19	.5	23	
15	5	11	?	3	1	6	
7	6			4	1		
22	6			10	1		
9	?			11	1		
6	?			14	?		

Table 7.2
Individual Desiccation Toilet Pertinent Data (Sonacala)
(a=top half of vault; b= bottom half of vault)

Parmaters for Individual Toilets / Parameter Measured	LowLimit	4a-br:Ash A	4b-br Ash A	7a:Fastidio	7b-br::Fast	8a1-br: Sto	8b-br: Stoo	22a-br: We	22b-br:Wet/T	24a-br:Vil.(	24b-brick	11a1-br/blk(	11a2-br/blk:	11b-br/bl	11c-fg :Ostr	25a-soil	26a-soil	27a-soil	Blank	UpLimit
									22b-br:Wet/Trash											
Total N% (No/Acid Pre-treatment)	1.0	0.5	0.7	2.0	2.0	1.6	1.2	0.9	0.6	0.5	0.6	0.6	0.7	0.4	0.5	1.3	1.1	0.4	0.1	2.6
Total C%	---	9.8	10.9	10.9	11.2	9.4	9.4	10.8	6.9	7.6	14.2	10.2	9.7	9.8	11.0	12.6	9.6	0.2	11.4	----
C:N (No/Acid Pre-treatment)	---	19.3	16.0	5.6	5.7	6.0	7.7	12.2	11.2	14.8	22.3	16.0	15.0	22.8	20.9	9.5	8.4	0.6	96.9	
mg/kg Ammonia		235.7	1007.4	1716.8	474.2	1861.0	2630.7	308.0	470.0	629.9	353.5	305.3	375.0	528.6	403.5	1389.6	285.9	245.6	259.5	
5-day moisture (% of Total Weight)	10.0	4.8	7.4	18.2	23.4	25.7	30.2	29.2	23.4	6.4	6.6	10.5	28.7	29.3	12.4	33.1	35.0	6.9	17.1	20.0
5-day volatile solids	20.0	9.5	7.0	28.3	18.9	23.6	22.5	22.7	15.7	12.9	16.0	11.8	18.1	6.3	7.8	23.0	24.4	3.6	2.1	30.0
5-day ASH	80.0	90.5	93.0	71.7	81.1	76.4	77.5	77.3	84.3	87.1	84.0	88.2	81.9	93.7	92.2	77.1	75.6	96.4	98.0	70.0
ASH / VS Ratio	4.0	9.5	13.3	2.5	4.3	3.2	3.5	3.4	5.4	6.8	5.2	7.4	4.5	14.8	11.9	3.4	3.1	26.5	47.8	
TOTAL SOLIDS	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SOUR 5-DAY (actual) mg O/g VS/hr	1.5	18.9	4.3	6.7	3.7	16.9	13.4	5.7	3.8	4.7	1.9	17.7	9.5	23.6	4.7	11.3	12.7	11.2	0.0	4.0
SOUR 10-DAY(actual) mg O/g VS/h	1.5	6.3	17.2	3.5	6.9	12.7	5.3	8.8	3.8	33.4	8.7	20.3	6.1	9.5	2.6	0.0	0.0	0.0		4.0
SOUR 5-DAY mgO/g TS/hr	0.5	1.8	0.3	1.9	0.7	4.0	3.0	1.3	0.6	0.6	0.3	2.1	1.7	1.5	0.4	2.6	3.1	0.4	0.0	1.5
SOUR 10-DAY mgO/g TS/hr	0.5	0.6	1.2	1.0	1.3	3.0	1.2	2.0	0.6	4.3	1.4	2.4	1.1	0.6	0.2	0.0	0.0	0.0	0.0	1.5
10-day moisture (30% is flooded)	25.0	45.6	25.6	32.9	36.8	40.3	40.6	44.7	30.6	36.2	31.7	15.7	39.4	38.8	35.9	-	-	-	-	30.0
5-day MPN/g (less than)	1000.0	2.0	2.0	2.4	2.5	2.5	11.2	2.8	2.5	2.1	2.0	2.2	65.2	108.8	2.3	459.6	75.2	130.4	13.6	1000.0
MPN 5-day Upper CI (less than)	1000.0	0.3	0.3	0.3	0.4	0.4	3.6	0.4	0.4	0.3	0.3	0.3	21.2	35.7	0.3	165.0	24.4	47.6	5.0	1000.0
MPN 5-day Lower CI (less than)	1000.0	14.2	14.3	17.0	17.6	20.2	34.7	19.8	17.4	15.0	14.4	15.7	201.1	331.8	16.0	1280.0	231.6	357.5	37.1	1000.0
10-day MPN/g (less than)	1000.0	3.4	2.6	2.8	3.0	3.3	3.2	11.7	2.8	3.1	2.6	2.4	12.6	32.6	2.9	0.0	0.0	0.0	0.0	1000.0
MPN 10-day Upper CI	1000.0	0.5	0.4	0.4	0.4	0.5	0.5	3.6	0.4	0.4	0.4	0.3	4.0	12.3	0.4	0.0	0.0	0.0	0.0	1000.0
MPN 10-day Lower CI	1000.0	24.3	18.5	19.9	20.9	23.3	22.9	38.1	20.0	22.0	18.7	16.6	39.1	85.9	20.6	0.0	0.0	0.0	0.0	1000.0
Lab pH (1:5) <7.5 to 8.6>	8.0	9.7	8.7	6.8	6.7	6.6	7.0	8.5	8.5	9.2	9.2	8.6	8.2	8.4	8.8	8.0	8.1	8.4	8.9	9.0
Aluminum (Al)	-	7360.0	5852.0	23640.0	21300.0	21965.0	22857.0	6418.0	7393.0	14893.0	15062.0	4881.0	9096.0	7761.0	5425.0	199849.0	35725.0	1869.0	2878.0	-
Boron (B)	-	99.0	98.0	-4.8	-12.0	-3.0	-11.0	31.0	21.0	4.3	1.9	57.5	19.0	52.0	72.0	-8.0	-10.0	-4.0	-12.0	-
Calcium (Ca)	54000.0	242640.0	238971.0	81230.0	94802.0	70764.0	78487.0	145623.0	97677.0	83892.0	86534.0	221943.0	165067.0	213216.5	228326.0	128177.0	21099.0	2453.0	279530.5	54000.0
Copper (Cu)	4300.0	54.0	54.0	52.6	37.5	28.0	28.0	57.0	57.0	26.4	26.9	72.0	43.0	59.5	56.0	10.5	14.0	4.0	4.0	4300.0
Iron (Fe)	-	4053.0	3262.0	11568.0	9996.0	11293.0	11821.0	5764.0	7962.0	10026.0	9929.0	12327.0	6170.0	5529.0	2816.0	10575.0	17831.0	5973.0	2012.0	-
Magnesium (Mg)	Minimal	24173.0	23306.0	17766.0	12434.0	10800.0	13205.0	14413.0	10578.0	10557.0	10236.0	18830.0	17129.0	18981.0	20263.0	6608.0	10179.0	830.0	15581.0	Minimal
Manganese (Mn)	-	159.0	159.0	268.0	290.0	272.0	333.0	161.0	164.0	217.0	226.0	165.0	161.0	174.0	139.0	217.0	444.0	79.0	50.0	-
Molybdenum (Mo)	75.0	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.4	-0.4	-0.3	-0.3	75.0
Phosphorus (P)	32000.0	9705.0	12726.0	10503.0	14180.0	12249.0	10568.0	13689.5	12332.0	4710.0	5285.0	15857.0	12497.0	14538.0	14560.0	918.0	1201.0	287.0	106.0	32000.0
Potassium (K)	17000.0	28915.0	28229.0	15753.0	13816.0	12228.0	14495.0	16666.0	13934.0	19728.0	20467.0	19757.0	17032.0	12902.0	19063.0	2457.0	3929.0	241.0	384.0	17000.0
Sodium (Na)	4500.0	3645.0	3346.0	4928.0	2699.0	4416.5	3498.0	3863.0	3189.0	1951.0	2103.0	4621.0	3081.0	2156.0	4574.0	203.0	229.0	205.0	198.0	4500.0
Sulfur (S)	1300.0	4057.0	5960.0	5245.0	4514.0	3361.0	2367.0	3094.0	2845.0	3545.0	3814.0	3544.0	4212.0	2800.0	3571.0	1231.0	826.0	8.0	1097.0	1300.0
Zinc (Zn)	7500.0	218.0	225.0	195.0	227.0	179.0	139.0	245.0	203.0	145.0	173.0	185.0	211.0	234.0	213.5	56.0	61.0	17.3	9.7	7500.0
Solvita Carbon (out of 8)	6.0	7.5		6.5		4.0	4.0							7.0	6.0	6.0	6.0	6.0		8.0
Solvita Ammonia (out of 5)	4.0	4.0		1.5		3.8	3.8							1.5	1.0	5.0	5.0	3.0		5.0
Maturity Index (out of 8)	4.5	7.5		3.5		4.0	4.0							4.0	2.0	6.0	6.0	5.0		7.0
Temperature Waste		63.3	63.3	60.8	60.8	61.9	61.9	64.7	64.7	67.7	67.7	60.8	60.8	60.5	66.8					-
Termparature (Air) Inside Shelter		66.0	66.0	63.7	63.7	58.0	58.0	62.0	62.0	62.0	62.0	59.7	59.7	58.7	79.7					-

Note: LOWER AND UPPER LIMITE VALUES NOT ALWAYS VALID

Table 7.3

Pertinent Means, Standard Deviations, and Allowable Limits (Sonacala)

Means & Limtis for Toilets			SOIL			TOILETS ONLY		TOILETS	TOILETS ONLY				
(Sonacala)						ALL Toilets(Only)		AND SOIL	Top Halves		Bottom Havles		%
5-Feb-08	LowLimit	Blank 28a-bn	Mean	Std. Dev. A	UpLimit	Mean	Std. Dev. A	Std. Dev. A	Mean	Std. Deviation A	Mean	Std. Deviation A	Decrease A-> B
Parameter Measured													
Total N% (No/Acid Pre-treatment)	1.0	0.1	1.0	0.5	2.6	0.9	0.5	0.6	1.0	0.6	0.9	0.6	3.1
Total C%	---	11.4	7.5	6.4	----	10.1	1.7	1.9	9.8	1.1	10.4	2.4	-6.5
C:N (No/Acid Pre-treatment)		96.9	6.1	4.8	----	14.0	6.1	6.4	12.7	5.2	14.3	7.3	-12.4
mg/kg Ammonia		259.5	640.4	649.2		807.1	734.9	777.1	776.0	704.4	910.7	872.8	-17.4
5-day moisture (% of Total Weight)	10.0	17.1	25.0	15.7	20.0	18.3	9.9	9.1	17.6	10.5	20.0	10.5	-13.7
5-day volatile solids	20.0	2.1	17.0	11.6	30.0	15.8	6.9	6.6	18.1	7.0	14.4	6.5	20.6
5-day ASH	80.0	98.0	83.0	11.6	70.0	84.2	6.9	6.6	81.9	7.0	85.6	6.5	-4.6
ASH / VS Ratio	4.0	47.8	11.0	13.5		6.8	4.2						
TOTAL SOLIDS	100.0	100.0	100.0	0.0	100.0	100.0	11.0	0.0	100.0	0.0	100.0	0.0	0.0
SOUR 5-DAY (actual) mg O/g VS/hr	1.5	0.0	11.7	0.8	4.0	9.7	7.2	6.9	11.4	6.2	8.4	8.5	26.3
SOUR 10-DAY(actual) mg O/g VS/h	1.5		0.0		4.0	10.4	8.5	8.8	13.0	10.6	8.6	4.7	34.1
SOUR 5-DAY mgO/g TS/hr	0.5	0.0	1.99	1.4	1.5	1.4	1.1	1.1	1.9	1.0	1.1	1.0	44.4
SOUR 10-DAY mgO/g TS/hr	0.5	0.0	0.0	-	1.5	1.6	1.1	1.2	2.4	1.3	1.2	0.4	47.7
10-day moisture (30% is flooded)	25.0	-	-	-	30.0	35.3	7.8	7.4	36.4	10.2	34.0	5.7	6.5
5-day MPN/g (less than)	1000.0	13.6	221.7	207.8	1000.0	15.0	31.8	34.0	11.3	23.8	21.5	42.9	-90.0
MPN 5-day Upper CI (less than)	1000.0	5.0	79.0	75.4	1000.0	4.6	10.5	11.3	3.3	7.9	6.8	14.2	-104.2
MPN 5-day Lower CI (less than)	1000.0	37.1	623.0	572.4	1000.0	53.5	93.9	100.5	43.3	69.6	71.7	127.7	-65.6
10-day MPN/g (less than)	1000.0	0.0	0.0	0.0	1000.0	6.4	8.3	8.8	5.6	4.5	7.8	12.2	-38.9
MPN 10-day Upper CI	1000.0	0.0	0.0	0.0	1000.0	1.7	3.3	3.5	1.4	1.7	2.4	4.9	-71.7
MPN 10-day Lower CI	1000.0	0.0	0.0	0.0	1000.0	27.9	18.0	19.3	26.2	8.8	31.2	26.9	-19.0
Lab pH (1:5) <7.5 to 8.6>	8.0	8.9	8.2	0.2	9.0	8.2	1.0	1.0	8.2	1.2	8.1	1.0	2.0
Aluminum (Al)	-	2878.0	79147.7	105892.2	-	12407.4	7282.7	7445.7	12579	7697	13371	7476.1	-6.3
Boron (B)	-	-12.0	-7.3	3.1	-	30.3	39.0	28.5	29	38	25	43.1	13.8
Calcium (Ca)	54000.0	279530.5	49909.7	66704.2	54000.0	146383.8	69176.3	81315.5	144480	69768	134948	71385.3	6.6
Copper (Cu)	4300.0	4.0	9.5	5.1	4300.0	46.6	14.8	15.7	48	16	44	14.8	7.9
Iron (Fe)	-	2012.0	11459.7	5978.3	-	8036.9	3374.6	3059.7	8743	3328	8083	3188.1	7.5
Magnesium (Mg)	Minimal	15581.0	5872.3	4717.7	Minimal	15762.1	4749.5	3623.2	16238	4796	14456	4963.7	11.0
Manganese (Mn)	-	50.0	246.7	184.3	-	206.3	61.6	63.3	200	52	224	72.9	-11.9
Molybdenum (Mo)	75.0	-0.3	-0.3	0.1	75.0	-0.3	0.0	0.0	0	0	0	0.0	6.9
Phosphorus (P)	32000.0	106.0	802.0	467.9	32000.0	11678.5	3323.0	3548.2	11330	3567	11605	3406.9	-2.4
Potassium (K)	17000.0	384.0	2209.0	1856.5	17000.0	18070.4	5191.6	2904.8	18583	5227	17307	6002.5	6.9
Sodium (Na)	4500.0	198.0	212.3	14.5	4500.0	3433.6	979.6	1062.7	3786	1024	2832	606.8	25.2
Sulfur (S)	1300.0	1097.0	685.7	627.4	1300.0	3780.6	974.0	798.0	3865	721	3717	1349.0	3.8
Zinc (Zn)	7500.0	9.7	44.8	23.9	7500.0	199.5	32.0	33.3	197	32	200	37.3	-1.7
Solivita Carbon (out of 8)	6.0		6.0	0.0	8.0	2.5	1.5	1.4	6	2	5.5	2.1	8.3
Solivita Ammonia (out of 5)	4.0		4.3	1.2	5.0	1.1	1.4	1.3	3	1	2.6	1.6	14.9
Maturity Index (out of 8)	4.5		5.7	0.6	7.0	4.2	1.8	0.9	5	2	4.0	2.3	20.0
Temperature Waste			-	-	-	63.3	2.7	-	63	3	63.2	2.7	-0.5
Termparature (Air) Inside Shelter			-	-	-	62.9	5.5	-	62		61.7	3.0	-0.2
			NOTE: UPPER AND LOWER LIMITS NOT ALWAYS VALID										

considered to represent baseline values of existing concentrations of the parameters investigated. Some baseline concentrations of contaminants were higher than treated desiccated material. One sample of a local sand used was collected and analyzed (number 28a) and used as a blank. Approximately 18 waste samples were collected. Additionally, testing with the Solvita® kits was done on-site on some of the samples collected of the 8 toilets.

7.1.5 Sample Variation by Depth of Sample

The sample results were compared for the waste removed from the top half of the vault in repose (suspected less decomposition) and the bottom half (suspected more treated). The following observations were made: 1) the mean SOUR from the top half to the bottom half of the vault did decrease by 44.4 percent and 47.7 percent for the 5- and 10-day values respectively, and the mean Solvita® maturity index decreased 20 percent. These results indicated that there was a significant amount of treatment that occurred between the time of deposition of the waste in the bottom and top halves of the vault.

Moisture readings were not as conclusive. The bottom samples showed more moisture than the top half of the vaults with mean 5-Day moisture values of 17.6 with a standard deviation (sd) of 10.5 for the top and 20.0 ± sd 10.5 for the bottom. Since this is a waste that when introduced is at its most saturated state and therefore should have no potential for moisture to leach out, there should be no downward movement of liquids, thus eliminating migration as a contributing factor. There were operational problems in some toilets such as the introduction of urine to the vault that could provide an explanation for unexplained moisture levels. Another possibility is that the exposed surface of the waste on the top of the pile may be assisting the drying out of the waste in the upper half. Last of all, the variability in the data, as demonstrated with the standard deviations above is most probably one of the more significant reasons.

The mean MPN values for fecal coliform for the top and bottom halves of 43.3 ± sd 69.6 and 71.7 ± sd 127.7, respectively, showed no statistical difference in their results due to those large standard deviations. Since the detention times were very long, limited conclusions can be made in reference to the relative treatment of the fecal coliforms between the two halves. Earlier in the period of repose, it is suspected that there would have been a difference in the MPN values between the two halves as microbial die-off occurred over time and over the depth of the vault. In regards to other significant parameters, there were no other significant reductions or increases between the two vault halves.

7.2 Other Projects

Two other projects where desiccation toilets were built and investigated were in Guatemala and in Northern Mexico**.** In the Guatemala project, it appears 390 samples each from vaults in use, three samples each from filled vaults and 20 samples each from processed compost were collected from simple family compost latrines (in Spanish, “latrina abonera sencilla familiar" (LASF)). This toilet is the same concept, technology, and configuration as the Sonacala desiccation toilet; however, the vault dimensions were unclear. It was assumed they were significantly similar in size. The basic conclusion was that the desiccation toilet is a low-cost appropriate alternative for sanitation systems at the domestic level for the treatment of human waste and for agricultural purposes, with considerable level of acceptance. Funding was obtained from IDRC (believed to be the International Development Research Council) for a three-year study to support other institutions and to study the technology (Xet, 1988). In the Northern Mexico project, a University of Texas researcher built and investigated approximately four desiccation toilets and found that the desiccation toilet worked well also (Redlinger et. al., 2001).

7.3 Individual Factors

Following is a description of all the technical factors that influence the success of the desiccation toilet. In the section for each parameter, other influenital parameters are discussed. As the previoiusly-discussed parameters in turn influence other parameters, they then are discussed in those preceding section. The repitition of concepts from section to section provides for a comprehensive understanding of each parameter independently.

7.3.1 Potential for Waste Vector Attraction

Vectors are considered any agent that has the capacity to carry disease. Insects and microbial organisms are the most significant vectors that transmit disease after coming in contact with the waste pile. The mechanism of transmission is most commonly through bites directly on people or by their transmission of the disease to human food or water supplies. Human beings, through hand-to-mouth contamination, hand-to-food, et cetera are another form of transmission. Animals also can carry the diseases in waste through its consumption, for example by dogs, or pigs, commonly known as a pig latrine. When the contaminated animal then comes in contact with people, their food, or their habitation, they then transmit the disease.

7.3.2 Hydrogeology and Climate (Existing and Required)

The geological characteristics of this region do not adversely effect the implementation of the desiccation compost toilet technology. The sub-surface which is very rocky actually makes the desiccation compost toilet, which all can be built above ground the most feasible option from a construction perspective. The other two of the three common sanitation facilities—the pit latrine and conventional waterborne systems—all require extensive excavation, which at the best is very expensive (through use of very heavy machinery and/or blasting with dynamite). Different families attempted to construct pour-flush toilets. At one site, after a very difficult excavation down approximately four feet, a large boulder was encountered which prevented the completion of the proposed adsorption pit (cesspool) for a septic system.

This part of Mexico is a temperate zone. The temperatures range from 80 to 95 degree Fahrenheit half of the year from approximately March through August (the dry season—known as "la secia") and approximately 75 to 90 degrees Fahrenheit in the wet season from September through February (known as "las lluvias"—the rains).

Sonacala borders a federal highway (with significant bus and other traffic from Mexico City two hours away) then extends upward on a dirt/rock road. It is very roughly estimated that the length of the village is approximately ½ to 1½ miles long and the relief is one hundred to five hundred feet. These measurements were very approximate and depended on the line of travel, as ground slopes varied significantly in different portions of the village.

In some sections, the slopes are steep enough that rainfall created stormwater runoff that traveled downhill and physically impacted the vaults of the desiccation toilets. This was the case with bathroom 22 and was believed to be one of the reasons for that bathroom being abandoned. When the exterior vaults are wet, this decreases the rate of desiccation of the waste. With this toilet, the water content of the waste was high. The exterior bottom part of the wall of the vaults appeared to be wet and have water stains indicating past wetting cycles. The other reasons for abandonment were that the family desired a waterborne system and they had young children. The believed use of the compost toilet would be difficult for their young children. Incidentally, this was the son of the sanitation project technician/promoter. Regardless, this toilet, even with the moisture problem caused by the geological characteristics, was still used for approximately ten years.

7.3.3 pH

Although pH seems to be a very simple parameter, the evaluation of it in the process required a comprehensive explanation. It involves the evaluation of a) the pH values that are necessary for microbial growth and treatment, 7.5 to 8.6 (Tchobanoglous and Burton, 1991), closer to neutral according to other sources, b) the pH value required for the physical-chemical treatment process, and c) pH values found in the local soils, and the pH of the additives introduced—the lime and the ash. In the Sonacala toilets, the mean pH of the finished waste was 8.2 ± sd 1.2 for the upper vault halves and 8.1 ± sd 1.0 for the lower vault halves. The range of values measured which were mostly in the 8.0 to 9.3 range (with the lowest value at 6.6 and the highest at 9.7) can be seen in Figure 7.1 for each toilet. The pH for two of the most successful Sonacala toilets (number four and twenty four) was 8.74 and 9.17, respectively, for the waste in the lower half of its vaults. As can be seen, these were significantly higher than the mean. In the Guatemala toilets, the pH of the 390 active vaults was 8.73 ± sd 1.15 and the pH of the finished waste was 9.16 for 20 samples tested. The results from these two projects provide good mutual validation of pH ranges between 8.73 and 9.17. As a result, a pH of 9.0 is being considered as a central value for finished waste.

Also important to the analysis is the potential pH value of urine (which is believed to be more typically acidic) and the pH value of local soils which were mostly in the range of 8.5 to 9.0. The exclusion of the typically-acidic urine from the toilet's vault is critical in maintaining high pH values in the waste in process. The pH found during the process was believed to be influenced by a combination of the amount of ammonium present, the amount of mixing that was

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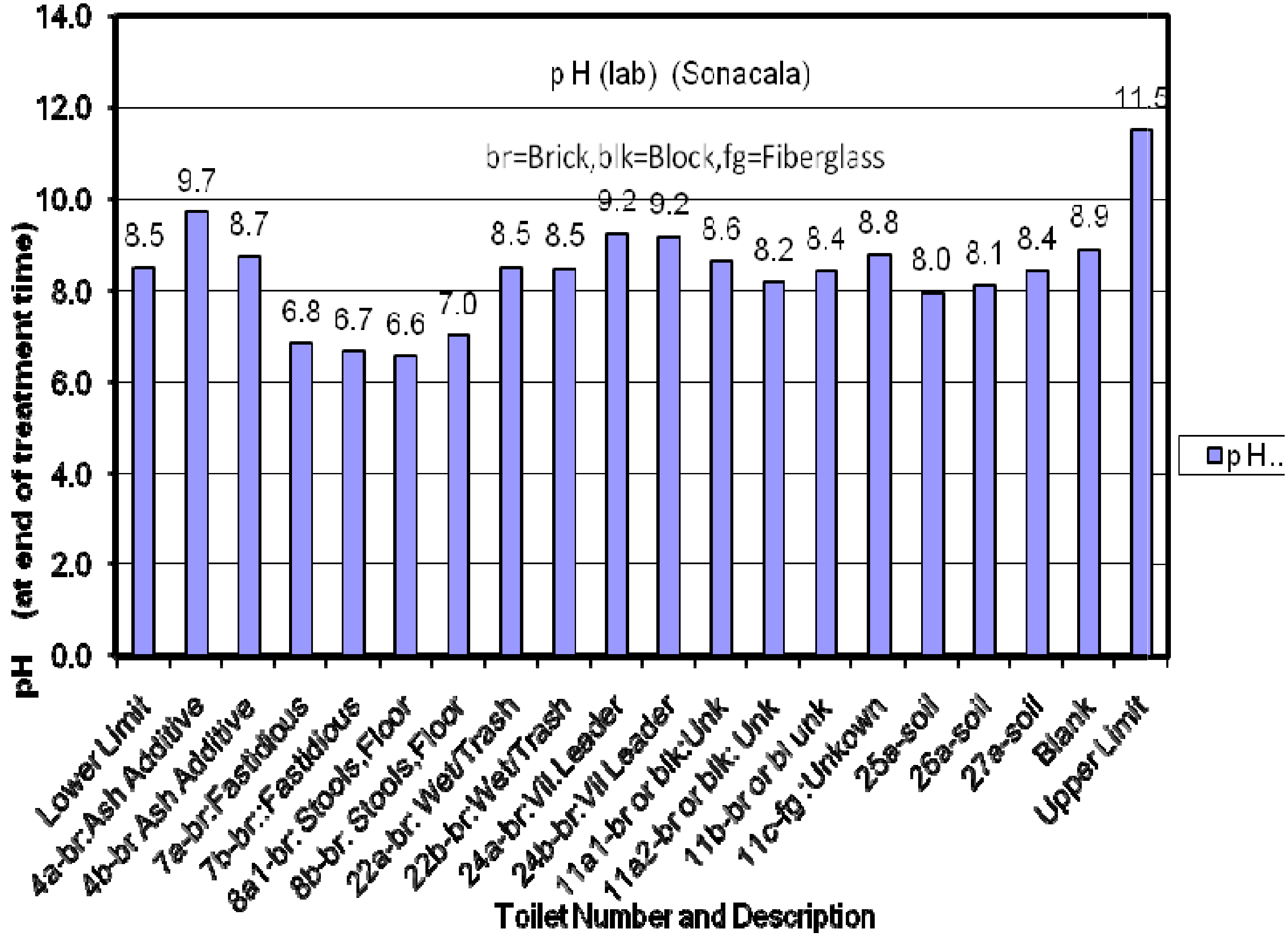

Figure 7.1 pH of Finished Desiccated Waste Samples (Sonacala) (a=top half of vault; b=bottom half of vault)

performed and of course the amount and continuity of lime and ash introduced to the vault. As described above, quicklime is the primary material relied upon to achieve the alkaline environment. When the family uses a wood-burning stove, they usually have an ample supply of wood ash. The largest component of wood ash (about 25 percent) is calcium carbonate. Wood ash has a very fine particle size, so it reacts rapidly and completely in soil and thus is a good liming agent.

The change in pH over the life cycle of the toilet is of interest. It is believed that the pH is higher earlier in the process. A reasonable explanation for this belief is that during the active stage when, and if, lime is continuously being added the pH values are higher. This could be the case if the quantity of lime applied was more than was actually needed. There was more lime (an excess) than was needed for the ammonium treatment and thus the higher pH. The other condition is that lesser amounts of lime are applied (or there is higher ammonium/excrement introduction). As the ammonium is converted to ammonia, and the ammonia has dissipated, the hydroxide molecules from the quick lime are used up and therefore the pH value decreases. More waste is being applied or is present than can be treated. On the other hand, continued generous use of lime, with relatively low newly introduced amounts of excrement, will cause pH levels to increase and be higher at the end. Both cases of higher or lower pH at the end of the process or any point in the process are reasonable. Level of mixing will influence these scenarios.

Obviously there is a strong recommendation that generous, continual applications of lime should be used from the standpoint of maximizing its use for water, odor, and pathogen removal, but perhaps limiting the quantity when there are plans for it to be applied to already alkaline soils. Also to be considered is the suggestion from a local professional (Anorve, 1988) that an equal mix of lime, soil, and ash be used, 1/3 of each component. When these three components are thoroughly mixed for a homogeneous end product, there is less concern with the unlimited generous application of this material. From the standpoint of the user and treatment, large quantities are preferred. Generous application ensures complete coverage of exposed stools, which creates a less disagreeable visual sight. The white color of lime provides an aseptic appearance.

Another strong recommendation is made on the through mixing of the waste both during the active stage and upon removal at the end of the stage of repose. The mixing at the end not only provided researchers with a more representative value of the actual pH value, but also benefits in the end use of the desiccated material. The final end use of the material depends upon the actual composite pH value. This pH-specific waste could either be recommended for a) generous application on acidic soils, b) limited careful use on alkaline soils, or c) re-use as an additive in the toilet at any pH, particularly if the pH or alkalinity values are very high.

The Guatemala study indicated that the effect of pH was more influential than the humidity in respect to the bacterial content of the finished waste. This was evident where the humidity values where less than 30 percent and still significant values were encountered of fecal coliforms (Xet, 1988). Accordingly it was concluded that the use of lime and the associated change in pH of the soil are more important in the overall treatment process than reduction of water content. On a similar note, elevation of temperature to remove water content only removes water content; whereas the application of lime both removes water and raises pH. It is clear that the process is not just a desiccation process. In fact, it is an alkaline desiccation process. The alkaline environment is probably also more effective in the die-off of spores and eggs, as opposed to the moderate ranges of temperatures and moisture content typical in this toilet. A more accurate name for treatment process in this toilet is an alkaline desiccation process.

The processes at two families provided additional insight on the effect of pH. In Sonacala, there were several toilets with acidic pHs. The pH was 6.56 to 7.0 for toilet 8 for the top and bottom halves of the waste pile. This was the family who closed both vaults, were defecating on the floor, were under a lot of economic hardship, and whose home was located at the top of the hill. Also this indicates that they probably had very poor maintenance, little if any use of lime, and possible urination into the toilet.

Urine can be acidic or alkaline. Some factors indicating urine to be more acidic is starvation or dehydration, and diarrhea. Sodium and excess acid retained by the body increases. Alkaline urine, usually containing bicarbonate-carbonic acid buffer, is normally excreted when there is an excess of base or alkali in the body. Secretion of acidic or alkaline urine by the kidneys is one of the most important mechanisms the body uses to maintain a constant body pH. Some families' diet in this area would be high in salt and this family, although probably not experiencing starvation or complete dehydration, could definitely be moving in that direction. (RNCEUS, 2008). Even more likely, is that the urine could well have been acidic due to a reasonable likelihood that users may have had regular occurrences of diarrhea, very common in Mexico. Diarrhea, in addition to sometimes being caused from microbial organisms, can also be caused by water that has poor treatment leaving many solids in the water. These solids stimulate the lining in the gastrointestinal tract which causes the bowels to spasm. These muscle spasms propel the contents of the intestines rapidly, causing diarrhea.

If the urination or excretion had not taken place recently, it is not likely that this would have influenced the pH of the waste. Urea, the chief constituent of urine, decomposes rapidly so non-decomposed urea is seldom found in other than very fresh wastewater (Tchobanoglous and Burton, 1991). However in the case of this family, where defecation was occurring on the floor and there was no evidence of urine on the floor, it is likely that the users were urinating in the vault. If the urine was acidic and recent and very little lime was being used, it is very reasonable that these were the causes of the lower pH at Toilet 8.

The desiccated waste from Family 7 also had an acidic pH of 6.84 and 6.66 for the top and bottom pile halves of the waste pile, respectively. Acidic urine is the suspect there also since a) the urine discharge hose was reported as leaking, and b) this family, who had great maintenance of the toilet, was using significant amounts of lime. Bleach, sodium hypochlorite, was being used on the floor which has an aqueous base. This being the case, possible bleach introduction through the basin/floor interface would not explain the lower pHs. Acidic urine was most likely the sole culprit, since inadequate lime use was apparently not a contributing factor at this toilet.

Finally, in evaluating the extremes, it was seen that an acidic environment is not typical nor desired for this toilet, and an alkaline environment is required. As a result of the above analysis, it is being established that a pH value of ten for a composite sample of finished waste removed at the end of the period of repose be the minimum required value for the successful use and operation of this toilet. The allowable minimum value could be decreased with the length of the detention time (period in repose). A toilet with a longer detention time could have a lower acceptable pH value. As time passes, the pH value of the final desiccated material should move toward neutral, but never reaching it. This 9.0 required pH at removal time is based on a waste that was well mixed during the active stage of the vault and is a composite value at time of withdrawal.

Intermittent values of pH during the active stage in the Sonacala toilets were not monitored and more definitive recommended values were even harder to establish. Since the mean pH of the samples from the active vault for the 390 Guatemala toilets was 8.73 ± sd 1.15, combined maximum of 9.88, and they appeared successful based on pathogenic indicators, and Redlinger et. al. (2001) recommended a pH of 10.0 as a minimum, it is being established that a pH value of 10.0 for a composite sample of waste removed during operation be the minimum required value while the vaults are in use. This operational-phase assessment parameter is important because it is during the operation of the toilet that assessment of the toilets and feedback to users is most important. Assessment cannot wait until the toilet is in repose in order to pull and test a finished waste sample. At that point, more or less, the toilet has already succeeded or failed. At a temperature of 77 degrees F ammonium volatilizes almost 100 percent at a pH of 11 (see Appendix A). At pH of 10.0, about 90 percent volatilization occurs which is satisfactory. The quantity of additional lime to raise the pH by one unit is probably not cost effective or necessary.

As can be seen, pH has a very strong effect on the treatment of the waste in the desiccation toilet. Feedback and simple explanation to users on influential factors (such the effect of urination into the toilet, the desiccation aspect of lime, et cetera) is beneficial to their understanding the technology and being able and willing to *provide the adequate use, operation, and maintenance.*

7.3.4 Alkalinity

Alkalinity results from the presence of hydroxides, carbonates, and bicarbonates of elements such as calcium, magnesium, sodium, potassium, or ammonia. Of these, calcium and magnesium bicarbonates are most common (in domestic wastewater). Alkalinity helps to resist changes in pH caused by the addition of acids. Alkalinity is expressed in terms of equivalency of calcium carbonate (Metcalf and Eddy, 1991). Alkalinity is dependent on pH and occurs in three different ranges. The three types of alkalinity and their approximate pH ranges are bi-carbonate alkalinity, HCO^{-}_3, (pH 4.5 to 8.3), carbonate alkalinity, $CO_3^{=}$ (pH of 8.3 to 12.7), and hydroxide alkalinity, OH^- , (pH > 12.7); no confirming source was readily available. The total alkalinity is the amount of acid required to react with the hydroxide, carbonate, and bicarbonate. (Sawyer, McCarty, and Parkin, 1994). Obviously hydroxide alkalinity is the most basic of the three types. Not only does pH affect soils, but so does alkalinity. Controlling alkalinity is shown below in Equation 12:

$$H_2CO_3^* \leftrightarrow H^+ + \underset{(99\%\ CO_2)}{HCO_3} \qquad \text{Equation 12}$$

Alkalinity, not pH, was the limiting factor in some samples analyzed. Alkalinity will be discussed further in the section below on the agricultural value of desiccated compost. An example calculation of the effect of alkalinity on soils and the resulting limiting application rate of the desiccated material to the soil is shown in Appendix D.

7.3.5 Temperature

The temperature of the waste, the inside of the shelter, and the general ambient temperature were all evaluated. Temperature in the waste in the desiccation toilets, and its influence on their treatment process were very different than other treatment processes, that is, aerobic nutrient removal processes and anaerobic digestion. Aerobic degradation processes are optimum around body temperature, 98 degrees Fahrenheit (Redlinger et. al., 2001). In aerobic processes, the reaction rate for microbial growth doubles approximately for every 10 degree Fahrenheit rise in temperature (Bates and Roy, 1984). In anaerobic digestion of waste, mesophillic bacteria require 85 to 100 degrees Fahrenheit and thermophillic much higher temperatures of 120 to 135 degrees Fahrenheit. The EPA requires a temperature of 52 degrees Celsius, 125.6 degrees Fahrenheit (for 72 hours and a minimum pH of 12) (USEPA, 2004).

In addition to pH for the desiccation toilet, waste processes, temperature and time are important factors in keeping pathogen survival low. Temperature is affected by air supply, carbon/nitrogen ratio, and water content (Bates and Roy, 1984). While it is very important to regulate these three processes for the multrum clivus compost toilet, it is not as critical for the desiccation toilet. Since the desiccation toilets operate mostly indifferent to oxygen, low or slowly decomposed and released nitrogen levels, limited moisture, and without any external heating, the temperatures are very close to ambient temperatures. In this area of Mexico the temperature is in the 75 to 95 degree Fahrenheit range for most of the year. Although relative humidity was not measured, it is known that the region is relatively dry, becoming very dry in middle months of the year. With the dry environment and the alkaline process, the desiccation process is ideal. The warm, external ambient temperature combined with the large amount of heat released internally by the quick lime exothermic reaction work well together to dry the waste from inside and outside the vault. Mixing of the waste will introduce some oxygen and could prevent heat from being trapped in the pile.

Although regulation of temperature in this process is not important, the actual temperature is significant. The technology is only known to be successful in warm climates. The three geographical areas being studied all have hot environments—Guatemala and central and northern Mexico. The original location of the toilet in Vietnam was known to be in a complementary environment. Temperature specifically affects the desiccation process in two ways in this toilet. First, the obvious one is through the supply of external heat to evaporate water from the waste. The other effect of temperature is in the inter-granular (inter-molecular) environment where the chemical reactions are occurring.

With the encountered temperatures, it is evident that no significant composting was occurring, at least not at the time of sampling. Temperatures much lower than those found in the above other treatment processes were encountered in the finished desiccated waste. The range of temperatures in the waste from the brick toilets were 60 to 68 degrees Fahrenheit (average 63.7) and block toilets were 60 to 61 degrees Fahrenheit (average 60.6) and from the fiberglass vaults were at the higher end of that range, at 66 to 67 degrees Fahrenheit (average 66.9). The temperature on the inside of the shelter was also measured. The inside temperature of the brick shelters (62.3 degrees F) and block shelters (59.2 degrees F) were slightly cooler by 1.4 degrees Fahrenheit (58 to 66 degrees F), than the waste temperature inside their vaults. On the other hand, the range of temperature inside the shelters of the fiberglass vaults was considerably higher by 8.8 degrees Fahrenheit (71 to 80 degrees F) than its range of waste temperatures. It is not believed that the temperature inside the shelters influenced the waste temperature in the vaults below. Since each vault is exposed on three sides, it is more possible that ambient temperatures would have been influential. Finally, the mean temperature inside the fiberglass shelters (75.7 degrees F) was significantly higher than the mean temperatures inside the brick shelters (62.3 degrees F) and block shelters (59.2 degrees F) by 13.4 degrees Fahrenheit and 16.5 degrees Fahrenheit, respectively. These higher shelter temperatures in the fiberglass shelters were definitely the reason for the lower acceptability of the fiberglass toilets. One of the most common complaints was that the temperature inside the fiberglass shelters was uncomfortably high therefore resulting in a lower acceptability and a decrease in the toilets' prestige. The recommended design feature to decrease the temperature in the fiberglass toilet shelter is to provide slats (horizontal openings) in the top of the shelter walls to allow hot air to escape. Although this should reduce temperatures some, due to the fiberglass material's ability to absorb and retain heat and believed less ability, as compared to the brick and block models, to reflect sunlight, it is highly unlikely that this will solve the problem significantly.

As noted above, the waste temperature in the fiberglass vaults was on the higher end of those found in the brick and block toilets. It is reasonable to consider that the much shorter detention time in the fiberglass vaults (mostly about one year) than the repose time in the brick and block vaults (3 to 6 years) was a factor. After 1 to 1.5 years, there should be no degradation occurring, so the temperature would have leveled off. Since the fiberglass material is more-or-less impermeable, and the brick and block toilets are porous, the fiberglass vaults most likely retained moisture and the brick and block walls allowed moisture (not water) to saturate the aggregate and with a temperature and moisture differential the wet aggregate materials probably allowed the migration of the moisture to the outside of the vault walls where the moisture could evaporate. Moisture was observed on the inside walls of some of the vaults. During the inspections data was not specifically sought on the presence of water on the exterior. However, it did appear that some of them had moisture on the surface—they were sweating.

In the Northern Mexico toilets, temperatures showed no difference throughout the pile height. This was an indication there was no nutrient removal process occurring (at least not at sample time) (Redlinger et. al., 2001). If there existed any significant temperature differentials between the top and bottom halves of the pile, or the pile and the atmosphere, those temperatures had already equalized by sample time. It is believed that no significant temperature differences exist with this technology and process.

In summary, in reference to temperature, there is no minimum waste temperature requirement that can be set. The regulation of the temperature is through keeping the moisture content low, adding lime, and mixing the waste to introduce oxygen and prevent pile compaction. The temperature that can be controlled is that of the environment. If physically comfortable, the brick and block toilets could be placed in a sunny portion of the yard, if one can be found, to increase external heating. The fiberglass toilet may have to be placed in the shade from the desirability standpoint while the vaults could be removed more frequently and placed in the sun to dry.

If periodic removal of the vault is not desirable or feasible, another possibility for the portable fiberglass toilet is that it could be moved around the site to experiment with sunny versus shady areas. This could determine if that would reduce the high temperatures in the shelter while not adversely affecting the treatment process within the vaults by locating the structure in too shady of area where these fiberglass bins with non-permeable sides may have a problem with releasing temperate and associated moisture. However, of the two fiberglass toilets, there is only one data point, whose 5-day moisture content was 12.41 percent on the lower end of the overall 5 to 30 percent values found. Also, the non-airtight enclosure that houses the fiberglass bin also contributes to releasing moisture. Location of the fiberglass toilet in a shady area may not present a problem. Finally, it is noted that with the limited data, these are just speculations that would have to be confirmed.

It is obvious that warmer, drier climates are more conducive to this technology, while this technology would have substantial problems in colder, wetter environments where substantial external heat and ventilation would probably be required. Finally, the block and brick material types appear to be more suitable from the temperature standpoints of heat and moisture release and acceptability of the shelter.

7.3.6 Detention Time (Period of Repose)

The average and range of detention times (or repose period) being considered are shown in Table 7.4 below. The data reported in the column labeled overall average was calculated based on all toilets investigated that were visited but not necessarily sampled. The column labeled sample averaged was for toilets whose samples were actually analyzed either in the field (with Solvita® kits) or the laboratory.

The fill time (FT) is the time span from when the first waste was introduced to the toilet to the time that it is closed. The detention time (DT) is the time span from the time that the vault was closed to the time that the contents are removed. If the fill time for the first vault is F_1 and the fill time for the second vault is F_2, then the detention time for the first vault $T_1 = F_2$. From that perspective, the treatment time for the first stool of waste deposited into the first vault would be F1 plus F2. That would provide an average treatment time of the waste in the first vault of (F1 + F2)/2. For example if F1 and F2 were 1 year each, then T1 = 1, and the average treatment time would be 1.5 years, and the time of treatment of the first waste introduced would be two years.

Table 7.4
Detention Times Considered (Years)

Toilet Type	Overall Average	Range	Sample Average	Range
Brick	4.40	3.0 to 6.0	4.4	3 to 6
Block(Non-sampled)	0.72	0.5 to 1.0	Unknown	Unknown
Block Sampled	See above	See above	4.0	3 to 5
Fiberglass	0.75	0.2 to 1.0	Unknown	Unknown
ALL TYPES	1.90	1.2 to 2.6	Unknown	Unknown
ALL TYPES	1.90	1.3	Unknown	Unknown

The detention times collected for 8 brick-type toilets had an average of 4.4 years ± sd 1.5 with a range from 3 to 6 years. The detention time for the sample from the one fiberglass toilet (number 11fg) sampled, and analyzed in the laboratory, was one year. There was one other fiberglass toilet (number 13) that was evaluated, only in the field with the Solvita® kit. (The detention time at the time of investigation of that toilet was 0.25 years.)

The detention time for the waste in the one block toilet sampled was unknown. The information obtained from the user was unclear in respect to whether the values provided were detention times or the physical age of the toilet. It appeared there was a misunderstanding as to what information was being requested. The range of values recorded was from 1 to 5 years. There were three samples analyzed, numbers 11a1, 11a2, and 11b. Sample 11a appears to have had a detention time of three years. This one sample was split equally into two samples—11a1 and 11a2. The two samples were then analyzed in the laboratory independently. Sample 11b appears to have had a detention time of five years. It was unclear as to whether there was a third sample with an additional sample that had a detention time of 1 year. It appears not. In summary it appears that the two original samples from the block toilet had an average detention time of 4 years ± sd 1, with a range from 3 to 5 years. They were the block toilets visited, but not sampled. They were reported to have an average DT for their current vaults in use or repose of 0.72 years.

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The reason some of these were not sampled was because the vaults were not full and the treatment was not finished.

Detention time information was collected on four of five fiberglass toilets. The detention times collected for four fiberglass toilets had an average of 1.31 years with the range being from .25 to 3 years. The accuracy of the DT reported for toilet 13 with a value of three years was suspect. Without that toilet, the average DT of the remaining three fiberglass toilets would be 0.75 year and the range 0.25 to 1.0 years. This range and average of 0.75 years appears more plausible for this toilet with its smaller removable single vault. Samples were collected and either field or laboratory analysis was performed on two of the five toilets. No detention time was known for Toilet 11's sample—sample analyzed in the laboratory—and since toilet 13 was suspect, no overall or sample averages could be determined.

Detention times of 0.75 to 1.0 years appear to be the most reasonable and practical considering all factors. As discussed earlier, a detention time of 6 to 12 months is the standard set by the *Water for the World Technical Note* (USAID, 1982) and it is the standard being promulgated here. This standard is set, with the condition that lime is generously added, along with satisfactory amounts of other additives (preferably ash and top soil), periodic leveling and mixing of the waste is accomplished, and urine is not introduced into the toilet.

This one year limit is applicable as long as these conditions are met and a realization that the pathogen indicator targeted is fecal coliform. If there is a concern for pathogens that produce spores or eggs, a longer detention time should be considered. However, note that anything over 1 to 1.5 years could sacrifice other more important project goals such as developmental group follow-up and, to a much lesser degree, possibly user cost.

Considering the above, a DT of 0.75 to 1.0 years could be a reasonable standard, more or less, regardless of the level of operation and maintenance provided. A case in point for this belief is the circumstances at toilet number 8. For an unconfirmed reason, indiscriminate defecation was occurring inside the shelter on the floor. Even with that being the case, the processes going forward inside the apparently closed vault no longer had much or anything to do with what operational practices were occurring during the fill time, how the second vault was being maintained, or the current operational conditions. The fact that the cycle was complete and the vault closed indicated a minimum level of O&M. Furthermore, it is reasonable to assume that if the horrific operational and maintenance habits being practiced at the time of the investigation were present for any extended period, the toilet conditions (odor and insects) would probably not have been tolerable and the toilet would have been abandoned completely. It is believed that the conditions present were only present for a couple of months (based on the number of stools present on the floor and the number of users). This period of extremely poor operation and maintenance, however, was only a small period of the 14 years of operation of this toilet. It is entirely possible that the vaults at this home were never emptied. The detention time of this vault was reported to be three years, so that would have made the operational period of the first vault 11 years. Since it is unknown if the vaults were previously emptied, no firm conclusions can be made on its detention time. It is known that since the 5- and 10-day MPN values for the fecal coliforms were below 12 for all of its samples that the waste was considered treated well from the pathogenic standpoint. The bottom line is that although the operational conditions were poor and the full history of the detention times were unknown; there was still a level of success that could be seen at this household.

One experienced local architect believes that six months of repose time for each vault is adequate (Anorve, 1988). Keeping in mind that six months of average repose time for each vault would provide an average treatment time of 0.75 years, significantly closer to the one-year standard, a repose time of six months is reasonable. Regardless, the one year of DT is being maintained for the sake of conservancy. The bottom line is that the size of the brick toilets with their large detention times (one even reported at 10 years), was oversized from a treatment perspective. Reduction of the detention times to one year is a great improvement.

The design and operation of the block toilets deserves consideration. The block toilets received favorable reports and since the design is basically the same as the proved brick toilet model, the block version should be considered further. Of particular interest are the vault sizes and operational procedures recommended by the governmental agency that supported that project. No information was available on sizing, design, and operational criteria promulgated by the state environmental agency that oversaw the construction of the block toilets.

7.3.7 Volumetric Considerations

The size of the vaults was definitely greater than necessary. Because the “footprint” (length by width) of the vaults and the shelter can not be changed for practical reasons, sizing is not a significant issue. Since the information on the number of family members and the actual depth of waste in the vaults was not considered very accurate, re-evaluation of this parameter would have been difficult. The number of family members was typically between 2 and 6. The size of each vault was approximately one cubic meter. Design equations investigated previously (Bates and Roy, 1984) are not considered to be accurate. Sizing is controlled by the above practical considerations. No changes in vault size are recommended. Reduced effective volume can be achieved by pre-maturely partially filling the vaults approximately 25% during construction prior to the vault concrete top being placed (poured).

7.3.8 Water Content

Depending on the location and character, the following terms are being used for different states of water: water content, moisture, water vapor, and humidity. Water content (moisture) refers to water internally held in the waste, moisture is water that accumulates on surfaces inside and outside the vaults, vapor being released from the vaults through evaporation is water vapor, and humidity is water suspended in air in the surrounding environment. The term moisture is also used synonymously in the sample results from the Louisiana State University laboratory.

The necessary value of water content of human waste for aerobic decomposition by microbial organisms is in the range of 30 to 50 percent. Normally stools contain 75 percent water (Jensen, Buffangelx, and Coul, 1976). Some microbial growth has been seen below 30 percent. Eggs and spores are more viable and can survive in harsher environments. Cysportioum and salmonella are two measures for more resistant organisms. EPA regulatory limits for moisture in municipal sludge treatment are not applicable to the desiccation toilet process, however, they can provide a starting point for consideration (sewage sludge must be air dried to achieve a percent solids greater than 50 percent, i.e., moisture content less than 50 percent, pH above 12 for 72 hours, and temperature of 52 degrees Celsius). The moisture content found in two of the three local soils was in the 33 to 35 percent range, however, with a mean of 25.0 ± sd 15.7. The third soil sample was 6.87 percent. The initial moisture content of the excreta was unknown. At a dilution (mixing) rate of 10:1 (10 parts soil, one part waste) the water content would be reduced to 25 percent. The important conclusion is that lime and mixing is still needed to reduce the water content to the desired level of less than or equal to 20 percent; plus, the addition of this much soil is impractical.

The range of the water content values of samples removed from the active and the full vaults in the Guatemalan toilets had a mean of 51.34 percent ± sd 15.10 and 44.02 percent ± sd 7.28 (see Table 7.5) respectively. In samples with values of water content ("humedad") greater than 50 percent (and pH lower than 7), the majority of the fecal coliform counts ("recuentos") were encountered (see Figure 7.2).

The five- and ten-day water content values of the samples removed from the toilets in repose in Sonacala are shown in Figure 7.3. The five-day values represented the actual initial water content in the waste after sample removal. The SOUR analytical procedures allow for an initial period in the laboratory prior to measurements to allow the microbes to "settle down" and reacclimatize to their new environment. After the initial readings at five days, water was added to the samples and they were incubated for 5 days to provide adequate time and conditions for microbial activity. This simulated potential worst-case field conditions where the dehydrated waste is dumped in a field and then is rehydrated through contact with rain or runoff. Since this is neither the recommended nor the common practice, this could be considered a conservative laboratory adjustment. The pH can be adjusted in this test also (as well as will be discussed in the Solvita® test). After ten days, a second reading was taken which represented calculated parameters after this initial ideal growth environment. Field moisture readings were taken with a field probe. A value of ten was completely saturated and a value of one was at the soil's driest state. There was a very wide variability in the results. Those values are not shown in Table 7.2 and Table 7.3. The oxygen readings in the laboratory were taken with an oxygen electrode.

The range of most of the 5-day moisture values were approximately 18 to 30 percent with a mean of 18.3 percent ± sd 9.9. The mean value affected the extreme values in the samples of toilets four and twenty-four. Those finished samples had extremely lower values in the 5 to 13 percent range. Of those toilets with these extreme values, the moisture values were 5 to 6 percent and were known to be successful and well accepted toilets. Those values were for toilets with long periods of repose of approximately three years. Very good operation occurred in those toilets also. As a side note, the water content of the sand sample was 17.09 percent. In some of the samples analyzed, saturation occurred at approximately 30 percent moisture content (see Figure 7.3).

Note that a designer of a technology must sometimes choose between scientific processes. In this case, a desired low-moisture range of 10 to 20 percent (as shown in Figure 7.3) is the chosen and desired range as well as the best treatment process—desiccation. Accordingly, the scientific process of microbial degradation is sacrificed for the sake of the desiccation process. This is another reason the toilet should be basically classified as a desiccation toilet and not a compost toilet. Consequently, the pH range of 30 to 50 percent as shown with the red bar (the second one) should not be attempted to be achieved. Some practitioners may try to operate the toilet in compost mode (higher moisture). This could cause odors and decreased social acceptance (see Figures 7.2 and 7.3).

Table 7.5

Analyzed Guatemala Desiccation Toilet Parameters

Cuadro No. 11
Parametros Analizados En Muestras De Abono Lasf

		Compost in Treatment	Compost in Full Closed Vault in Repose	Processed Compost
pH	n	390.00	3.00	20.00
	x	8.73	7.83	9.16
	s	1.15	.85	1.27
Humedad (%)	n	390.00	3.00	20.00
Water Content (%)	x	51.34	44.02	18.12
	s	15.10	7.28	11.57
Carbono (%)	n	390.00	3.00	20.00
Carbon (%)	x	5.84	4.07	2.22
	s	4.21	1.16	.90
Materia Orgánica (%)	n	390.00	3.00	20.00
Organic Material (%)	x	10.04	6.95	4.49
	s	7.22	1.98	2.02
Sólidos Insolubles (%)	n	390.00	3.00	20.00
Insoluble Solids (%)	x	71.62	78.40	88.00
	s	4.96	5.51	3.65
Ceniza (%)	n	390.00	3.00	20.00
Non-Volatile Solids (%)	x	75.16	78.40	88.00
	s	24.34	5.51	3.65
LEGEND: n= Number of Samples x= Mean s= Standard Deviation				

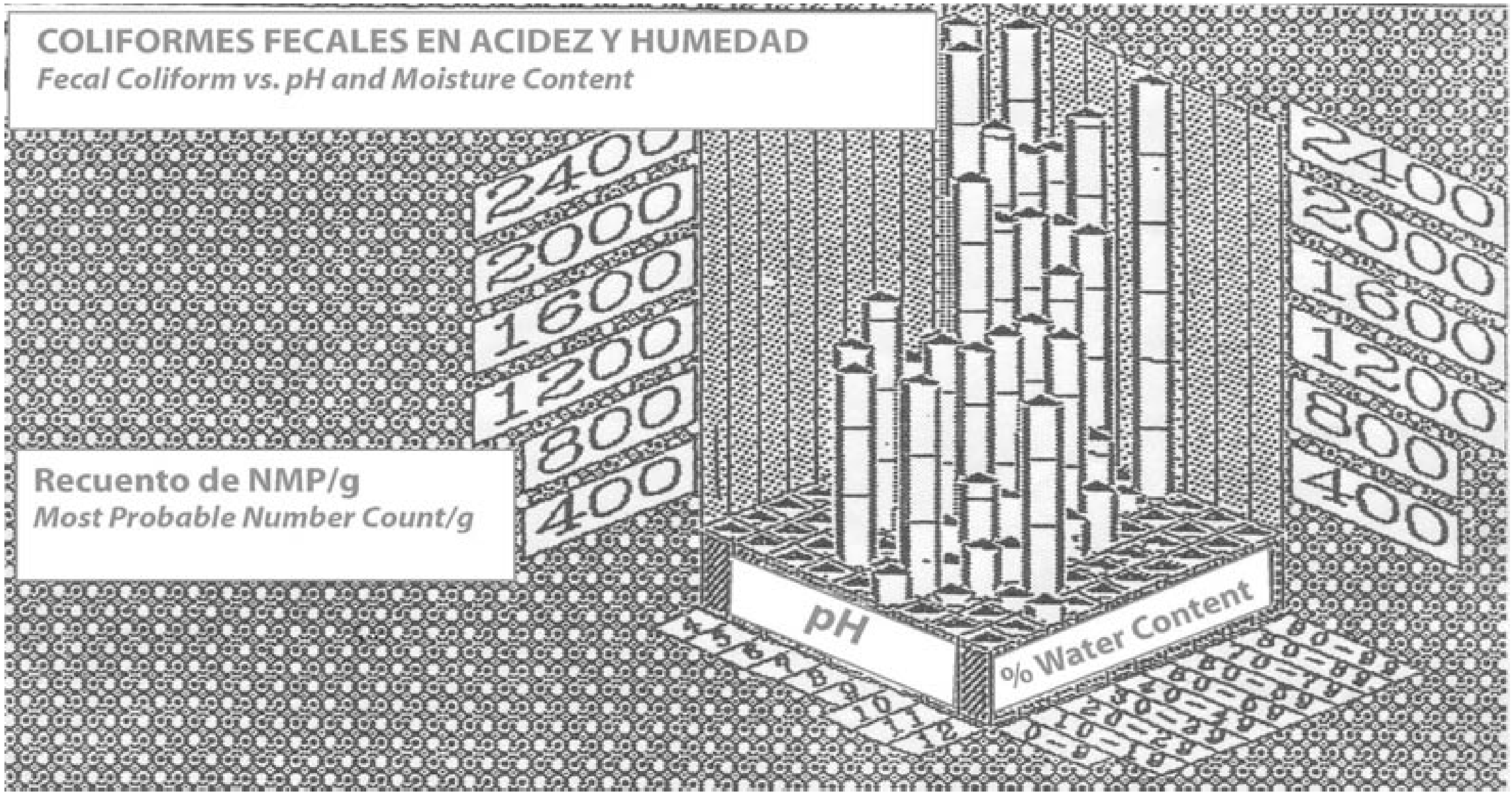

Figure 7.2 pH and Water Content Effect on Fecal Coliform (Guatemala) (Illustration by Anna Maria Xet (CEMAT))

Water Content (% Total Weight) 5 & 10 Day

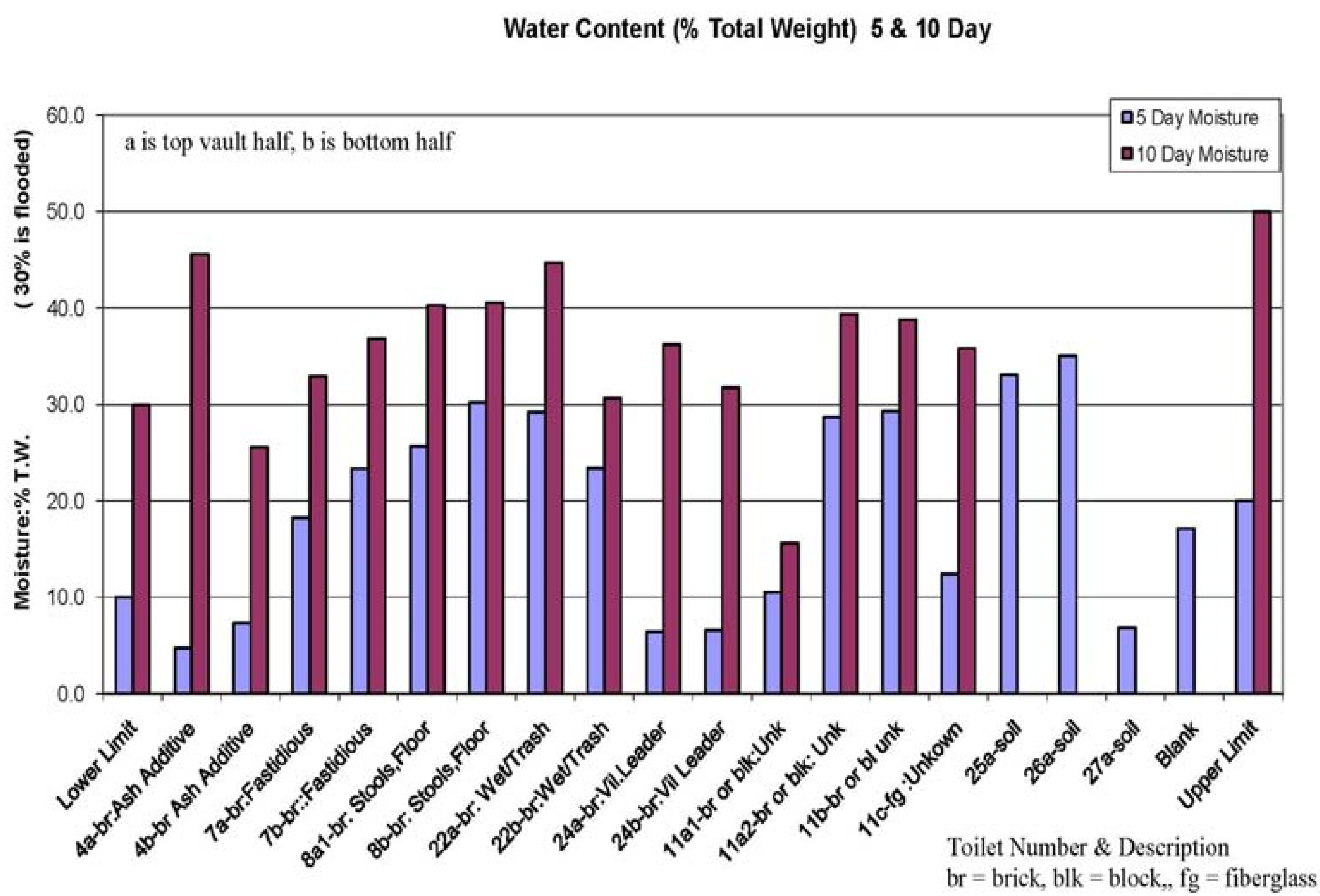

Figure 7.3 5- and 10-Day Water Content (% Total Weight) (Sonacala)

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The finished samples from the Guatemala project ("abono procesado") indicated a mean water content of 18.12 percent ± sd 11.57. (The repose period was not reported for those toilets.) As can be seen the moisture values for the two sets of data provide good verification of representative values in the desiccation process of this technology.

Mixing for the active vault contents should decrease moisture values and prevent waste pile compaction. The Guatemala samples indicated that mixing did decrease moisture values from 70 down to 30 percent and increased pH from 7.7 to 9.5 (Xet, 1988). Obviously, use of a drier additive with lower water content would reduce the water content in the waste from absorption, prevent pile compaction, introduce oxygen, and expedite desiccation. Increases in water content would prevent desiccation. Excessive moisture can drive nitrogen back from ammonia to ammonium, the opposite effect of eliminating nitrogen (see Equation 5) and odors would increase. This was reported by investigators in Sonacala and was seen at Toilet 2. As mentioned above, even though pH has a stronger direct influence on treatment, water content in desiccation is key and is the second most important parameter.

The recommended maximum limit for finished samples (those removed at the end of the repose period) is 20 percent. If attainable with reasonable retention periods of 1 to 1.5 year maximum, 5 to 15 percent would be ideal. If a biological (composting) process is desired, a minimum moisture content of 30 percent will be required with levels up to 60 percent. Intermittent water content in the waste in the active phase can be expected in the 20 to 30 percent range, moving down toward 15 to 20 percent or lower over the length of the process.

The most important passive operational issue is to keep the waste pile dry by not introducing liquids (the additional "active" operational issues being the addition of the additive and lime). Apparently due to inadequate user knowledge (and education), this requirement was not obvious to all users. Introduction of liquids to the vaults were encountered in three instances. Family 2, due to a lack of a facility in which to shower, used the shelter of a fiberglass toilet in which to sponge bathe. Through the non-watertight flooring, water probably entered the waste receptacle (flies were reported at this toilet). Secondly, it was reported that sometimes while seated, children urinated accidently, or on purpose, into the vault through the basin, instead of urinating into the built-in urinal. Thirdly, it was reported that men who did not want to be bothered with sitting just to urinate, attempt to urinate into the small built in urinal but "miss." Last of all, guest of the family have no knowledge whatsoever of the concept of the dry toilet and thus unknowingly urinate directly into the vault through the large toilet basin opening (this was reported to have happened at a party one evening).

In another case, moisture condensed and accumulated on the bottom of the seat cover, then apparently dripped onto the seat. After sitting on the moist seat, the thigh of the user was apparently burned from ammonia gas that condensed and converted back to ammonium or was in solution. After this occurrence, a toilet lid was designed that had a mesh material in the middle section of the seat that allowed the ammonia to escape through the toilet basin seat cover. The other alternative would be to leave the seat cover up to allow the vault to vent. Respiration pipes apparently do not always sufficiently allow the ammonia gas to escape. Moisture outside of the vault is an indicator of a process occurring inside in the waste. Here perhaps there was a high level of use, and perhaps even good treatment that was operated at a high capacity, treating large amounts of excrement (and associated ammonium) and thus producing large amounts of ammonia gas.

In summary, it is required that only excrement be introduced to the vaults and a dry and generous amount of additive be used, with use by no more than the maximum number of recommended users (typically 4 to 5 "full time", with seven as a maximum, including family members who are away often). Along with mixing of the vault contents and proper accommodation for ventilation, this type of operation and maintenance should produce a finished product with 20 percent water content, even with 10 to 15 percent potentially achievable, without undesirable insects and correct elimination of byproducts (ammonia and water).

7.3.9 Fecal Coliform and Other Pathogenic Indicators

Fecal coliform, an indicator of potential pathogenic microbes in the waste, has a regulatory limit of a density of 1,000 most probable number (MPN) per gram of total solids (dry weight basis) for class A sewage sludge. Alternatively, salmonella-species bacteria may be used as the pathogenic indicator for which the regulatory limit in sewage sludge is 3 MPN per four grams of total solids at the time the sewage sludge is used or disposed for sale or given away in a bag (USEPA, 2004).

The results, from a human health protection standpoint for pathogen reduction in the waste, were exceptional as indicated by very low fecal coliform counts. The upper confidence interval (upper CI) and the lower confidence interval (lower CI) were measured and reported along with the actual counts. The majority of the samples had fecal coliform in a range from 2 to 25 MPN/g, which the higher value is a factor of 40 lower than regulatory limits. The ranges of 5-Day fecal coliform values for all of the finished waste samples, for all toilet types, were from 2 to 109 MPN/g/TS with a mean of 15.0 MPN/g ± sd 31.8 (upper CI of 4.6 and lower CI of 53.5) with a 10-day mean of 6.4 ± sd 8.3 (upper CI of 1.7 and lower CI of 27.9). The differences between the fecal coliforms in the top and bottom halves of the vault were not significant. For purposes of being able to read the values in the table, the lower confidence intervals were plotted instead of the parameters' actual values. They are shown in Figure 7.4.

Even if fecal coliform limits are met, there still exists the possibility that other more resistant microbial organisms remain viable in the waste. Some pathogens that form spores or eggs may be less affected by treatment (USEPA, 2004). Cryptosporidium and Giardia cysts can be monitored as a better indicator of viable pathogens. In the northern Mexico toilets, there was a decrease in cryptosporidium from 46 percent to 0 percent positive after six months. For Giardia, there was also a decrease from 100 percent to 68 percent positive after six months. Although that assay does not measure viable oocysts and cysts, it is a valid indicator for their absence, which was the objective of that study (Redlinger, et al. 2001).

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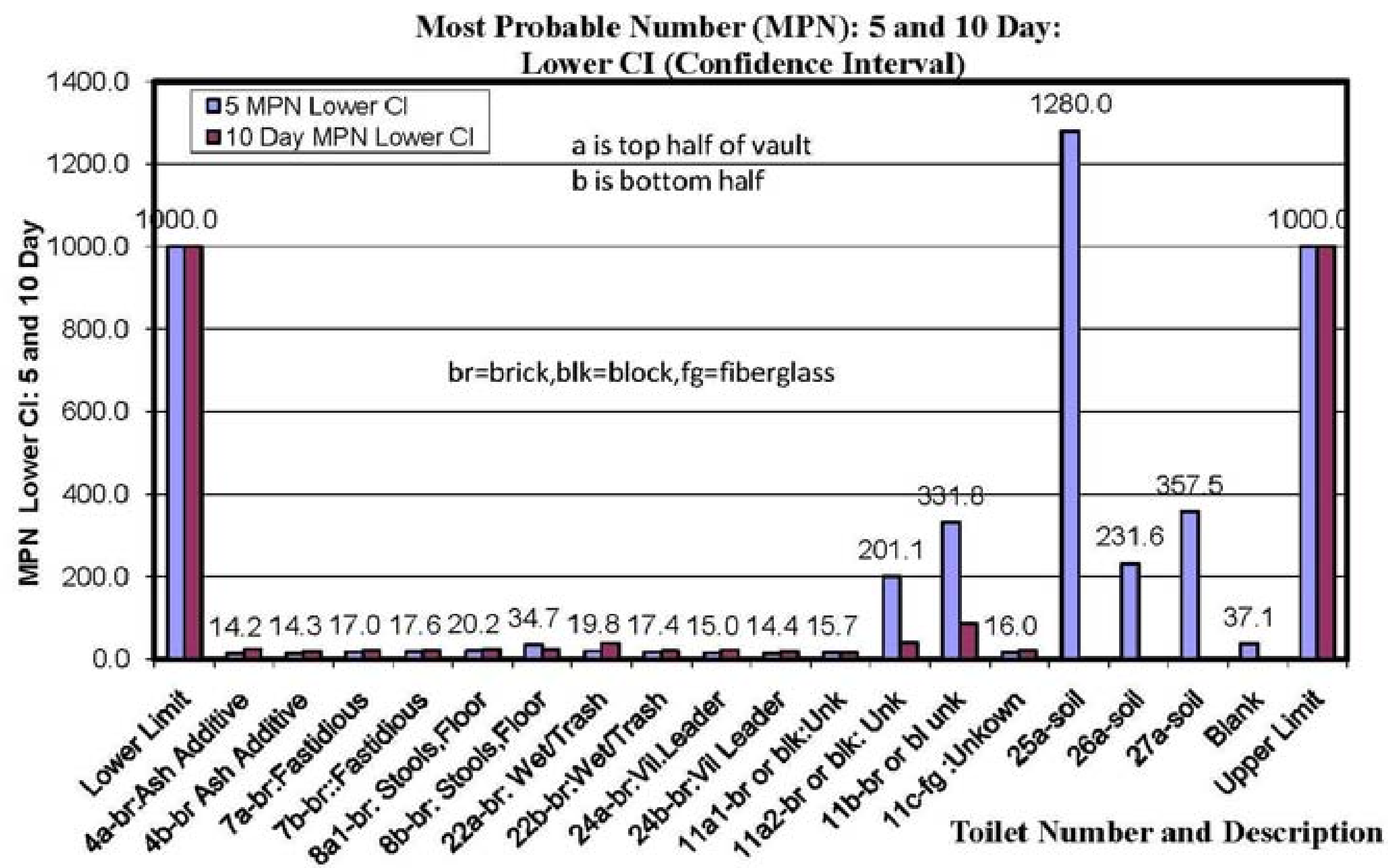

Figure 7.4 Most Probable Number Fecal Coliform: Lower CI (5- and 10-Day) (Sonacala)

One of the benefits derived from this international project was the incorporation of the significant work of Xet (1988) into the English scientific literature community. Before that benefit can be achieved for non-Spanish speakers a translation of terms from Spanish to English is required, which follows:

Ascaris Ova (egg) Count: Recuento de Huevos de Ascaris (RHA)
Total Viable Egg** Count: Recuento de Huevos Viables (RHV) <not just Ascaris>
Viable ** “Intestinal Worm” Count: this probably includes others:
Lumbrices is the general Spanish term usually referring to Ascaris, but also can include other worms such as pinworms, helminthes, etc.
Viable Ascaris Ova (eggs): Huevos Viable de Ascaris (HVA)
Helminth Egg (ova) Count: Recuento de Huevos de Helminthes*** (RHH)
*** Helminthes is a genus term in Latin (Genus appears to be a subgroup of a species).
Viability of Ascaris Ova Worms: VHA
This term appears just to be a modification of HVA

Finally, in the Guatemala study, “recuento de huevos Ascaris (translation Ascaris (ova) egg count) were at the following low levels based on interpolation of Figure 7.5 (Xet, 1988):

- Zero eggs at a pH of 8 and water content of 20 to 29 percent
- Zero eggs at a pH of 8 and water content of 30 to 39 percent
- Approximately 500 eggs at a pH of 8 and water content of 40 to 49 percent

Obviously from the standpoint of disease prevention, the desiccation bathroom, under the conditions tested, was excellent from the results of the Sonacala, the northern Mexico, and the Guatemalan studies. The only caveat placed on the Sonacala results is the long detention times of the toilets (particularly the brick ones, between 3 to 6 years). These were significantly longer than the USAID recommended minimum of repose period of 6 to 12 months. These also were longer than typical detention times in other projects. Since these levels may not be achievable at lower detention times, these results should not be expected at lower periods of repose.

Since recommendations are being made to reduce the available vault space in order to decrease detention times, fecal coliform values could go up. However, with these tested values, there is still plenty of leeway to make the trade-off of some treatment efficiency (specifically pathogen reduction) for more reasonable smaller vault space and shorter detention time. The logistical need to reduce available vault size and associated cycle length is so that users will have access to technical support from developmental workers who are not typically in the community for long periods of time, sometimes not even longer than the construction phase.

Although there were no dimensions available, the physical configuration of the Guatemala toilets (Xet, 1988) appeared to be very similar to the Sonacala desiccation compost toilets. Some of the other results from the Guatemalan toilets were as follows**:**

• Values for “Recuento de Huevos Helminthes (RHH)” (translation “Helminthes Egg<Ova> Count”) were reduced from 728 ± 2,331.2 in the vault in use to 50.0 and 127.47 eggs/g in the finished waste.
• Fecal coliform were reduced from initial values in the raw waste of 2,400MPN/g to 128 MPN/g.

“Recuento de Huevos Viables” (RHV)* (translation Total Viable Egg Count) was reduced from 4778 ± 6,403 eggs/g in fresh excrement to 0 eggs per gram in all the finished waste studied (XET, 1988).

*RHV is the principal indicator of decontamination of biomass in process (Xet, 1988)

• The effect of pH and humidity for this parameter (Ascaris Ova) was variable. Elevated counts of Ascaris Ova were observed at pH values greater than 10 and water content less than 30 percent.
• Fecal coliform counts decreased from 815.47 ± 1,046.35 MPN/g in the vault in use to a value of 158.05 ± 525.27 in the final product.
• Pit latrines sampled (the traditional status quo competing technology) created a favorable microbiological environment to the development of pathogenic microorganisms, which were reflected in fecal coliform counts of 1,884.22 ± 920.97 MPN/g.
• Viabilidad de Ascaris lumbricoides (VHA) (Viability of Ascaris “intestinal worms”) was reduced from values of 9.86 ± 25.3% in the vault in use to 0% in the finished waste. This value in the pit latrines was 22.3% ± sd 31.9%. This indicated the major effect of the process for the fecal material (Xet, 1988).

When the density of viable helminthes ova in sewage sludge prior to pathogen treatment is equal to or greater than one per four grams of total solids (dry weight basis) then reduced to less than one after treatment, then the sludge is Class A with respect to viable helminthes ova until the next monitoring episode (USEPA, 2004).

• There was a relationship between humidity and acid levels. The drier and more alkaline the environment, the better the system functioned with lower counts of fecal coliform, VHA, and RHV.
• The majority of the counts of fecal coliform were located in the region of pH less than seven and humidity greater than fifty percent. (These results provide strong validation of the operational parameters and success of the Sonacala toilets where most pH levels were in the range of 8 to 9 and water content in the range of 5 to 30 percent.)

7.3.10 Volatile Solids, ASH, and Organic Matter

In the analysis for the waste at the LSU Callegari laboratory, the amount of volatile solids was calculated. This parameter is used as part of the calculation of the SOUR as it was expressed in mg of oxygen lost per hour per gram of volatile solids. Much care should be exercised in evaluation values of SOUR since it is reported in various types of units from different groups. In addition to the Callegari LSU lab reporting method, tables formerly published in 2002 by the Solvita® company (see Table 7.8) reports SOUR for comparison reasons in units of mg oxygen consumed per gram volatile solids per day. Note those reported units are per day, not per hour.

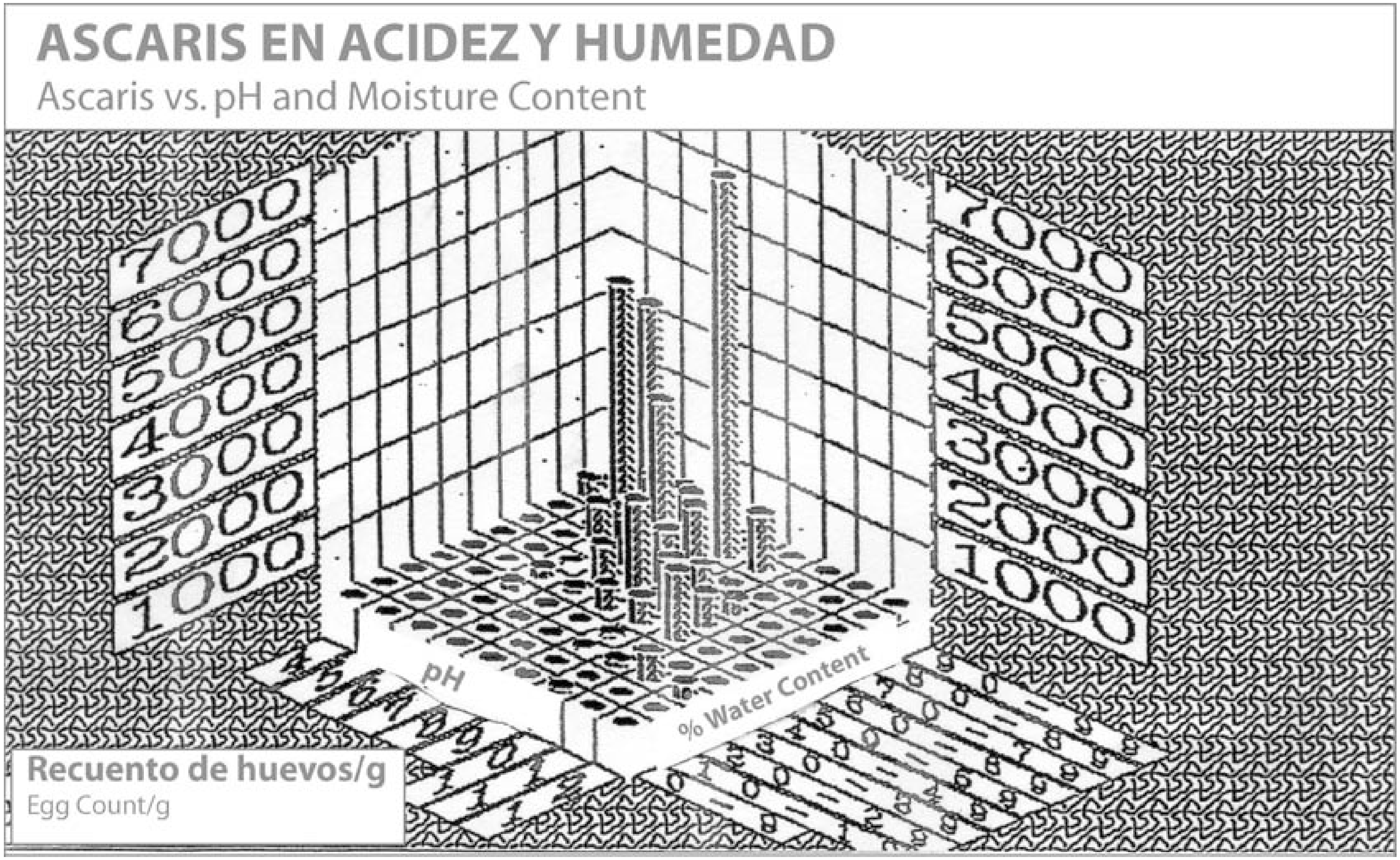

Figure 7.5 Ascaris Ova Egg Count (Guatemala Samples) MPN/ gram TS (dry weight basis)
(Original illustration by Anna Maria Xet)

Table 7.6
Compost Maturity Index Table
(Original Table by Woods End Research)

Compost Maturity Index Table[a]

use the A and C paddle color numbers and read across and down to where the columns meet

Solvita Ammonia Test Result is:		SOLVITA Carbon Dioxide Test Result is: 1	2	3	4	5	6	7	8
5	Very Low NH_3	1	2	3	4	5	6	7	8
4	Low NH_3	1	2	3	4	5	6	7	8
3	Medium NH_3	1	1	2	3	4	5	6	7
2	High NH_3	1	1	1	2	3	4	5	6
1	Very High NH_3	1	1	1	1	1	2	3	4

a. Example: If the NH_3 result is 2, and the CO_2 result is 6, then the Maturity Index is: 4

To prevent confusion, the Solvita® company no longer refers to the SOUR parameter in their maturity index table. Although their literature does not make this comparison, a testing procedure called "Test Methods for the Examination of Composting and Compost" has a published procedure for Solvita® testing, where they use units of O_2 consumed per gram of OM (organic matter) per day (Section 29.1). It appears that an equivalency is assumed by that reporting that organic matter is equivalent to volatile solids. The same procedure uses a different unit of measurement reported in Section 13.1 as mg O_2 per gram of Total Solids, OM per day. These assumptions have not been confirmed.

A summary of the reported units follows from the different sources:

Callegari:	mg O_2 lost	per gram of	Volatile Solids	per hour (2002 data)
Solvita®	mg O_2 consumed	per gram of	Volatile Solids	per day (2002:Table 3)
Test 05.08 (Sec. 29.1)	mg O_2 consumed	per gram of	OM*	per day 4/7/02
Test 05.08 (Sec. 13.1)	mg O_2	per gram of	Total Solids,OM	per day 4/7/02
EPA Title 40/503	mg O_2	per gram of	Total Solids(DWB)	per hour 7/1/04

As discussed in the previous section on SOUR, because of the lack of continuity and confusing use of units between different sources, a comparison of the values of these parameters was not made. The LSU Callegari Center units of mg O_2 lost per gram of volatile solids per hour was used for the data reporting; however since it was the EPA standard (based on total solids) that was used as the principal guide and the setting of the project standards, the Callegari data was converted to mg oxygen per gram total solids per hour. It was on the total solids basis that the data made the most sense. Further investigation and analysis would be beneficial to the industry to compare, contrast, and develop simple calculation methods to convert between the different units.

In addition to the purpose of measuring volatile solids as a required parameter for calculation purposes with SOUR, volatile solids are used as a measure of remaining organic matter in waste. The Solvita® test described previously is basically a measure of ammonium in the waste, not total organic matter and potential total oxygen demand. Ammonium is part of the oxygen demand, but only a part. The other larger part of oxygen demand is the carbon-based organic matter. Accordingly, the volatile solids test serves the additional role of indicating organic matter content. Organic matter content is significant in the analysis of the desiccation toilet from two perspectives. The first one is environmental protection, in which a maximum allowable VS limit must be considered, and the second one is from the standpoint of an agricultural soil amendment, in which a higher value is desired.

A normal amount (perhaps from the perspective as compost) of organic matter is considered to be 25 to 30 percent volatile solids, while 60 to 65 percent would be considered high (Iqbal, 2008). The Composting Council reports a range of 30 to 70 percent organic matter for compost developed for agricultural purposes (U.S. Composting Council, 2008). The mean organic matter in the toilets in Sonacala was 18.1 ± sd 7.0 for the top half of the vaults and 14.4 ± sd 6.5 for the lower half of the vaults.

As can be seen, this is quite low for the character of what is considered compost. This is one of the indicators showing that this technology, as operated in Sonacala, does not produce a very good compost (for toilets with lower detention time, it is possible the organic matter content could be significantly higher). The reason believed for this “loss of organic matter” is due to a biological process occurring in the toilet where microorganisms are consuming the solids, growing and proliferating, and then a die-off occurs. This is a typical cycle in wastewater treatment facilities that is controlled by food-to-mass ratios. When there is ample “food supply” (the excreta in this case), the microbes grow. Then the microbial community reaches it peak growth rate and population when the food supply is no longer adequate to support the larger biomass. Consequently, the solids—the organic matter, represented by volatile solids—is converted ultimately to dead microbe parts and microbial excreta, both very stable material. This loss of organic matter is believed to occur in the desiccation toilet, as evidence by visual observation of dead worms, similar to a white grub worm, until the water and/or food supply runs out, and pH conditions become unsuitable. This organic loss is evident in the samples from the top halves of the vaults of Toilets 4, 11 (brick toilet), and 11c (fiberglass toilet) which had very high ASH content values (low VS values) of 93.0, 93.7 and 92.3 percent respectively. Overall, the toilets had a high ASH content with a mean of 84.2 ± sd 6.9.

From the other agricultural perspective, organic matter content has benefit as a soil amendment. Based upon the three soil samples with a mean volatile solids content of 17.0 ± sd 11.6, a compost with a higher organic matter content would be helpful. Toilet 7, for example, with a volatile solids content of 28.3 percent is right at the lower limit of the values stated by the Compost Council. Accordingly, that toilet has a little more benefit as a soil amendment. It appears that many of these toilets with long detention times, although it was the cause of the low desired fecal coliform, also resulted in very low organic matter. If the toilet’s detention time is reduced, it is believed some of that organic matter content and value can be preserved while still obtaining sufficient pathogen die-off.

The EPA does have some requirements on volatile solids in its vector attraction reduction regulations. Even though they are not necessarily applicable, the regulated values can provide a starting point for consideration of standards. When bulk sewage sludge is applied to a lawn or a home garden, one of eight options on a VS requirement must be met. Option b1 states that the mass of volatile solids in sewage sludge must be reduced by a minimum of 38 percent. Keep in mind that sewage sludge is a liquid or semi-solid, whereas the desiccated material from the desiccation bathrooms is a solid.

The last potential application of the volatile solids parameter is in reference to the quality of the finished waste and the additive material and as a part of a quantitative ratio as a descriptor of treatment. The non-volatile solids, referred to as ASH, are calculated by subtracting the VS from the total solids. As can be see in Figure 7.6, the volatile solids and the ASH are calculated as a percent of total weight, and their sum equals 100 percent. As mentioned previously, wood ash reacts very well in soil. For this reason, an additive with a high non-volatile solids content (ASH) should be very good material for absorption of moisture and odors, due to the reaction of its calcium carbonate component with the moisture in the waste. The mean ASH value was 84.2 ± sd 6.9. A point of comparison, note that the ASH content of the local sand had a value of 98.0 percent. This material, particularly the samples in the 90 percent range, was basically inert, similar to sand. From a visual observation of the material, the material was very non-organic in nature and texture. From a physical inspection of the material by rubbing the material between the fingers, the materials of five of the samples are described below (see Table 7.7).

The above descriptions made up of physical inspection of the waste are very helpful in determining the actual character and nature of the end product. Once the samples have been discarded, this type of information is lost. These descriptions are valuable for field technicians as well as the analytical personnel in the laboratory and office. Agronomist and sanitation technicians who are responsible for field examination of local soils for their acceptability as drainfield are accustomed to making these characterizations. Tables with soil characterization by grain size, particle type, and color can possibly be obtained from governmental agencies, that is, Department of Health (DOH). Agronomist and composting organizations such as the U.S. Composting Council also have literature specifically for compost. This material appeared to be more of the character of a fine grain soil, or even silt, than a compost, or coarse-grained soil. These descriptions were made after having sieved the material and eliminating small rocks and wood particles.

Table 7.7

Visual and Physical Observations of Sample Color and Texture

Sample	Description
4	Light Sandy Dry Powdery Material
8	Dark Black Moist (Organic Appearance) Material with white (lime?) specs
11a	Light Gray Powdery Material (Medium Moisture to Dry)
22a	Medium Brown Sandy Material w/light specs throughout (Medium Moisture)
24	Sandy Brown Dry Powdery Material

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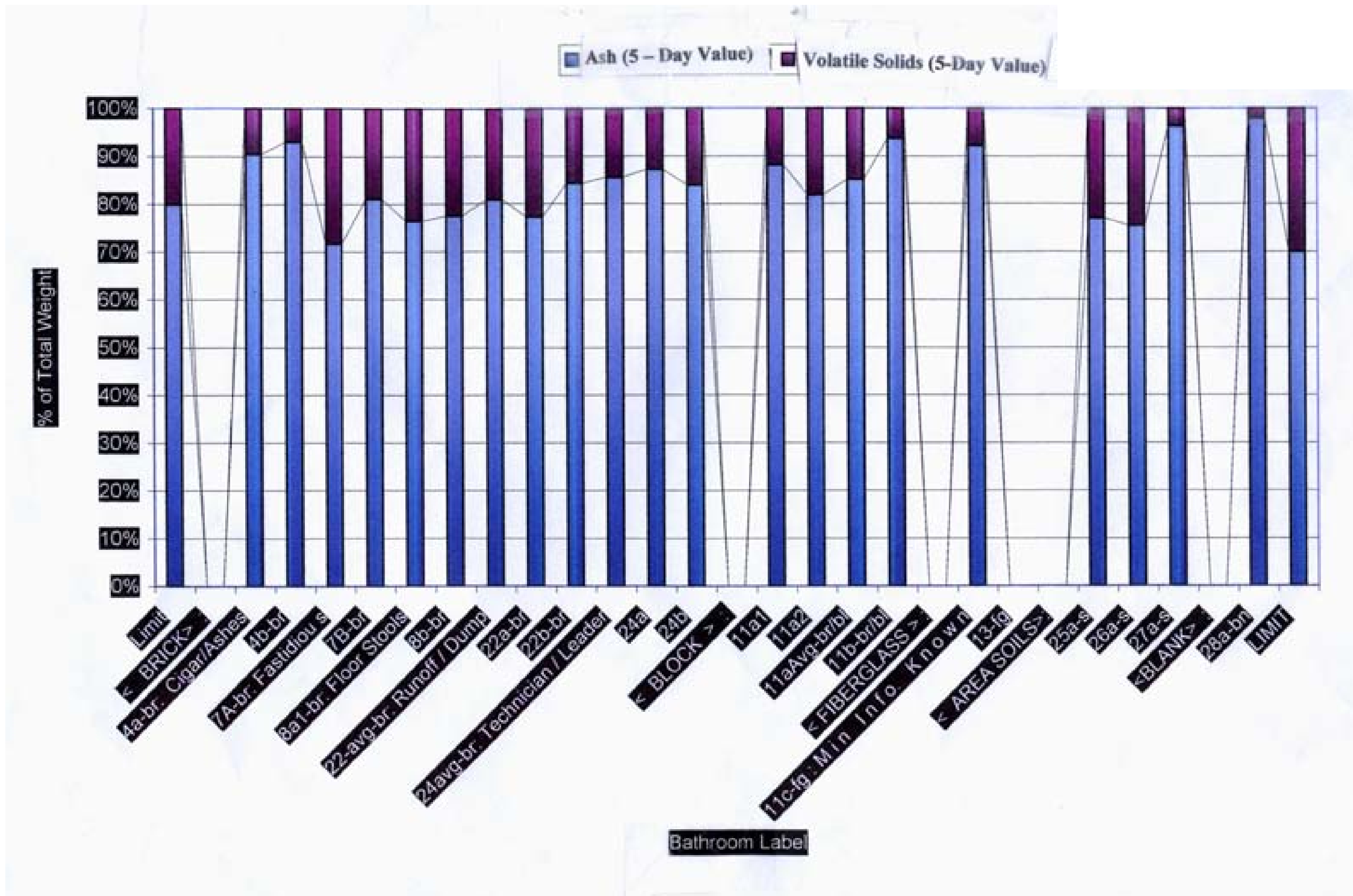

Figure 7.6 Volatile Solids (Organic Content) and ASH (5-Day)

The sample from Toilet 4 was the one with the second highest ASH content of 93 percent. It is believed that the additive contained a high amount of wood ash from a wood-burning stove the family used. Also, it is possible this family re-used the finished waste as the additive or at least one of its components. (It is known for certain that the brother of one of the family members re-used the finished waste from his toilet, number 24.) The finished waste sample, as described above, was a light sandy dry powdery material, which is consistent with the general description of wood ash. The potassium level, a measure of potash, was also measured.

The potassium content of 28,229 ppm of the finished sample from Toilet 4 appeared to confirm the reported heavy usage of wood ash (from a wood burning kitchen). The ash was considered to be a contributor to the success of that toilet.

It is believed that instead of such a high use of lime, when available, that wood ash should be tried to be used as a higher percentage of the additive. It contains 25 percent calcium carbonate, resulting in its similar ability to increase pH as lime (but not so drastically), can absorb odor better, should cover the waste better due to its broader dispersion pattern when tossed on top of the waste pile, and does not cost anything. The only consideration against this recommendation is that it would not be desirable, from an environmental perspective, if this encouraged users to cut down trees to burn to produce additive for the toilet. That being said, ash that is already available should be considered as a more significant additive component than was seen used in most households.

7.3.10.1 Discovery of a Novel and Unique Key Technical-Social Factor

In the course of this investigation a potentially helpful quantitative ratio was discovered. It is the ratio of non-volatile solids (ASH) divided by volatile solids (VS). A higher ASH/VS ratio measure would indicate an obviously high ASH content compared to its volatile solids counterpart, and also be indicative of a more stable nature of material. Also, it was discovered that almost all the data for this ratio fell between 0 to 10, with most of the values between 3 and 7. The value at Toilet 4 was 9.5 for the sample from the top half of the vault and 13.3 for the lower half sample. It is believed that this could be a good descriptor both helpful to the technician and as a simple understandable parameter that can be explained to villagers in terms of a material they understand and have experience with—wood ash. The other parameters such as SOUR, Solvita®, or volatile solids are all much harder parameters and concepts to communicate. Not only could ASH/VS be a descriptor of the additive, but further consideration is warranted to determine if it could be a good indicator of treatment (at least for the removal and/or absence of organic matter), just as volatile solids is an indicator of the presence of organic matter. Ash is a very common concept, even religiously—*from ash we were made to ash we will return*. Also, converting human waste into ash, and returning it to the environment is part of the promotional marketing of this toilet by some of its practioners. It is often explained as a cycle of consumption of corn, excretion of it as waste, use of it to fertilize corn, then

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continuation of the cycle. The ASH/VS ratio holds much promise as a link between the technical and social factors that has been sought out in this work.

7.3.11 Environmental Impacts: Oxygen Demand, Toxicity, and Vectors

In order to evaluate and address environmental impacts, there are six issues that must be addressed: 1) clarification of environmental objectives, 2) an understanding of the two measurement parameters of SOUR and Solvita®, 3) traditional standards for these two parameters for agricultural compost, 4) an understanding of the method of interpreting Solvita® field measurements, and interpretation of SOUR standards, 5) a very limited comparison of Solvita® and SOUR values, and 6) evaluation of the two techniques and establishment of a new standard for these two parameters based upon the desiccated waste results and the particular application and goals the desiccation toilet and the rural Mexican environment in which it exists.

7.3.11.1 Environmental and Other Objectives

When partially-treated human waste is disposed of in the environment, it can have harmful effects due to 1) the remaining oxygen demand that can be exerted on receiving streams, 2) increased vector attraction in the process of further degradation of the waste, and 3) potential phytotoxicity to plants. The Specific Oxygen Uptake Rate (SOUR) was used as a measure of oxygen demand that the waste could exert on the environment in which it is disposed or used, and the Solvita® Maturity Index (MI) for phytotoxicity—toxicity to plant life due to high nitrogen content. Although the Solvita® MI does have a relationship with oxygen demand, it is only indicative of the oxygen demand from the ammonium in the waste (Evans, 2008). It would not reflect the oxygen demand resulting from the organic matter in the waste. As discussed previously, volatile solids is direct measure for organic matter. All three parameters are indicators of vector attraction. SOUR and Solvita® are two of six respirometry methods published in *Test Methods for the Examination of Composting and Compost* (U.S. Composting Council, 2008). The use of volatile solids as part of these measurments is addressed in the those published test methods.

7.3.11.2 Regulations and Standards

In the United States, when bulk sewage sludge is applied to an agricultural land, forest, a public contact site, a reclamation site, a lawn, or home garden, a disease vector attraction reduction requirement must be met. One of these requirement options is the SOUR parameter and test. In the United States the SOUR for treated sludge, in an aerobic process, must be equal to or less than a set value. As mentioned previously, this value has units that are similar but different than other agencies using and reporting this parameter, for this reason care must be exercised in its evaluation and use. The SOUR value by the EPA is 1.5 milligrams of oxygen per hour per gram of total solids (dry weight basis) at a temperature of 20 degrees Celsius (USEPA, 2004). Note that this is on a total solids basis, whereas the parameters used below are based on volatile solids and/or are measured per day, not per hour. A former Callegari Center staff member quoted treatment standards as being between 0.3 to 1.3 mg oxygen per gram volatile solids per hour. The Woods Ends Research Laboratory's Solvita® literature implies a treatment standard of 0 to 0.167 mg oxygen per gram volatile solids per hour.

7.3.11.3 SOUR and Solvita®

SOUR is a laboratory technique and measurement parameter, whereas the Solvita® company Maturity Index (MI) is a parameter and a value derived from field measurements with a compost test kit manufactured by Woods End Research Laboratories, which is used principally for the evaluation of agricultural compost. Solvita® kits were used as an alternative to the more time-consuming and possibly more expensive SOUR measurements that can only be done in the laboratory. They provide a practical, relatively inexpensive way to measure oxygen demand in remote areas, where collection and transportation of samples is difficult and expensive. They also provide immediate feedback to technicians and users.

Table 7.8 shows the correlation that already was established between the Solvita® MI and SOUR by Woods End Research Laboratory. Tables 7.9 and 7.10 were developed from that correlation. It should be noted that because of confusion by readers of the comparison, this comparison has since been removed from the Solvita® literature; however, it still exists in the Compost Council published test methods.

7.3.11.3.1 Limits of Solvita Kit Use for Desiccation Toilets

Guidelines and limitations for the application and use of the Solvita® test kits for desiccation compost toilets are needed. Since the desiccation bathroom is not a marketed technology for this product, the test method described below, nor the analytical tables and procedures, described in the Solvita® testing pamphlet Version 3.5/2000, do not account for some of the particularities that come with the toilet, the most important of which is pH. Solvita® measurements are not accurate at pH levels higher than 8.5 (Evans, 2008). Since some of the samples of the desiccated waste material were above that value, an adjustment to the field procedure is necessary for future use with desiccation toilets with highly alkaline waste with pH values that are higher than 8.5. Moisture and carbon/nitrogen ratio values found in the desiccation toilet waste may not be representative either of the traditional compost targeted by the Solvita® product.

7.3.11.3.2 Guidelines for Adjustment of Solvita Kit Use

Two modifications are possible to adjust the pH to lower than 8.5. The first is by leaching some of the lime away from the sample. This could be done by placing the waste in a bucket with holes and pouring water over the waste. The leachate would drain off through the holes leaving behind a sample with less alkalinity and lower pH. The other possibility is by completely immersing the sample in a bucket of water and then pouring the top liquid portion in the bucket through a strainer—cloth or some type of local material like a burlap sack or agricultural bags used to haul and store crop. In both of these cases, the material would have to

Table 7.8
Interpreting the Solvita® Maturity Index
(Table by Woods End Research)

Equivalency to Other Tests

As compost ages, it normally goes from a fresh condition (Solvita #1-2) to a mature state (Solvita #7-8). This can take weeks to months, depending on the materials and method of composting. The following table presents an overview of this aging process and shows how other tests that are used to characterize stability can be compared to the Solvita test.

TABLE #3: Solvita® Compost Maturity Index and Other Indexes

			Equivalency to other maturity indicators[a]		
IF SOLVITA MATURITY INDEX IS:	**THE STAGE OF THE COMPOSTING PROCESS IS:**		DEWAR[(b)]	CO_2 Rate[(c)]	O_2-Rate[(d)]
8.	Inactive, highly matured compost, very well aged, possibly over-aged, like soil; no limitations for usage	"FINISHED" COMPOST	V	1	<3
7.	Well matured, aged compost, cured; few limitations for usage			2	5
6.	Curing; aeration requirement reduced; compost ready for piling; significantly reduced management requirements	Curing		4	11
5.	Compost is moving past the active phase of decomposition and ready for curing; reduced need for intensive handling	"ACTIVE" COMPOST	IV	6	16
4.	Compost in medium or moderately active stage of decomposition; needs on-going management	Very Active	III	8	21
3.	Active compost; fresh ingredients, still needs intensive oversight and management		II	10	27
2.	Very active, putrescible fresh compost; high-respiration rate; needs very intensive aeration and/or turning	"RAW" COMPOST		12	32
1.	Fresh, raw compost; typical of new mixes; extremely high rate of decomposition; putrescible or very odorous material		I	>15	> 40

a. Note: this table gives approximate equivalency based on average organic matter and density.
b. DEWAR = Dewar self-heating test using standardized Dewar Flask
c. CO_2 Rate = total mg CO_2-C evolved per g VS per day
d. O_2 Rate (SOUR) = mg oxygen (O_2) consumed per g VS per day

Table 7.9
Solvita Maturity Index Value for Known SOUR Range
(Original table by Woods End Research; modified by Author)

If SOUR (O_2 Rate) is: mg O_2 / gVS / day	Solvita Maturity Index:	SOUR (O_2 Rate) mg O_2 / gVS / day	State of Composting Process
0-4	8	0-0.167	Inactive, highly matured compost, very well aged, possibly over-aged, like soil; no limitations for usage.
4-8	7	0.167-0.333	Well-matured, aged compost, cured; few limitations to usage.
8-13.5	6	0.333-0.562	Curing; aeration requirement reduced; compost ready for piling; significantly reduced management requirements.
13.5-18.5	5	0.562-0.771	Compost is moving past the active phase of decomposition and ready for curing; reduced need for intensive handling.
18.5-24	4	0.771-1.000	Compost in medium or moderately active stage of decomposition, needs ongoing management.
24-29.5	3	1.000-1.229	Active compost; fresh ingredients, still needs intensive oversight and management.
29.5-36	2	1.229-1.500	Very active, putrescible fresh compost; high respiration rate; needs very intensive aeration and/or turning.
36-40	1	1.500-1.667	Fresh, raw compost; typical of new mixes; extremely high rate of decomposition; putrescible or very odorous material.

* This table gives approximate equivalency based on average organic matter and density.

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Table 7.10
SOUR Value for Known Solvita® Maturity Index Range
(Original table by Woods End Research; modified by Author)

If Solvita Maturity Index is:	**SOUR (O_2 Rate) mg O_2 / gVS / day**	**SOUR (O_2 Rate) mg O_2 / gVS / hour**	**State of Composting Process**
7.5 - 8.5	3	0.125	Inactive, highly matured compost, very well aged, possibly over-aged, like soil; no limitations for usage.
6.5 - 7.5	5	0.208	Well-matured, aged compost, cured; few limitations for usage.
5.5 - 6.5	11	0.458	Curing; aeration requirement reduced; compost ready for piling; significantly reduced management requirements.
4.5 - 5.5	16	0.667	Compost is moving past the active phase of decomposition and ready for curing; reduced need for intensive handling.
3.5 - 4.5	21	0.875	Compost in medium or moderately active stage of decomposition, needs ongoing management.
2.5 - 3.5	27	1.125	Active compost; fresh ingredients, still needs intensive oversight and management.
1.5 - 2.5	32	1.333	Very active, putrescible fresh compost; high respiration rate; needs very intensive aeration and/or turning.
0 - 1.5	40	1.667	Fresh, raw compost; typical of new mixes; extremely high rate of decomposition; putrescible or very odorous material.

NOTE: This table gives approximate equivalency based on average organic matter and density.

be allowed to dry out to the proper moisture content level—at least overnight. When the waste is squeezed by hand, it should not yield any free water. The other method to reduce the waste is simply by diluting the waste with soil. Generally speaking, a 1:1 mix should be used of the desiccated waste and the soil from the site, preferably where the waste will be land applied.

Moisture of the samples that are too dry (inhibit growth) or too wet (create anaerobic condition) must be modified prior to testing. The guidelines for those adjustments are described in the Solvita® pamphlet. If C/N ratios are between 25:1 to 35:1, after adjustment of the pH and the moisture, the test method may be applicable. Additionally any other possible limits of the procedure, as specified in the Solvita® materials by Woods End Research Laboratory, must be adhered to in order to insure that the test procedures below are applicable. .

Another possibility is that since it appears that the Solvita® test kit has been designed to monitor specifically compost with its typical carbon, nitrogen, and moisture properties, the test method may not apply at all with some samples or the treatment path drastically different. Section 7.3.11.6 below describes this further. If it is determined that the procedure is applicable, the conventional procedure for its use follows directly below in section 7.3.11.4.

7.3.11.4 Solvita® Kit Test Procedure for Conventional Compost

The Solvita® compost test kit procedure works as follows in this abbreviated summary:

1) Various sub-samples, preferably ten, are composited together to form one sample, and are screened if necessary to eliminate large objects that will not fit in the small test jars.
2) The moisture content is checked by the hand-squeeze method. If it is too wet, the test cannot be run.
3) The sample is placed in the test jar and equilibration procedures are followed that last from one to two days (for high pHs over 8.5, an acclimation period of two days is recommended).
4) Two gel paddles, one marked “Carbon-Dioxide” and the other marked “Ammonia” are inserted with the gel surface not allowed to touch the compost sample. See Appendix B for illustrations and part of the instructions.
5) The lid is closed and kept out of direct sunlight for four hours. The gel colors for both paddles are read from a color-coded chart that has numerical values associated with each color. These numbers represent the carbon dioxide respiration of remaining microbes. For the carbon dioxide paddle, a reading of 1 is high; 8 indicates no respiration; For the ammonia paddle, a value of 1 is high (> 4000 ppm for pH of 9.0, and, up to > 20,000 ppm for pH of 8.0). The implications of a high ammonia content (low color value), is that it potentially inhibits the growth of the microbes. An ammonia paddle value of 5 indicates that there is very little to no remaining ammoniacal nitrogen with values of 200 to 1000 parts per million (ppm) for pH values of 8.0 and 8.5, respectively. Figures 7.7 and 7.8 show the carbon dioxide and the ammonia paddle values, respectively, for the Sonacala samples. Once those values are known, the numerical maturity index value can be found

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on (see Table 7.6). Also, the conceptual location of the waste in the decomposition process can be estimated as shown in Figure 7.9. Other interpretations can be made from the ammonia paddle value in Solvita® Tables 5, 6, and 7 not shown.

6) The Maturity Index is determined by lining up the carbon and ammonia paddle numbers in Table 7.6 (previously presented) to read their intersection which is the value of the Index. This index is used in interpretations in various charts (Solvita Pamphlet version 3.5/2000 Table numbers 2, 3 and 4, not shown). Figure 7.13**,** shows the value for the maturity index for the Sonacala samples. Most simply and most importantly, the maturity is determined from a scale of 1 to 8 with 1 being raw waste, a 7 being well-matured compost and cured, and an 8 indicating highly mature and possibly over-aged.

7.3.11.5 Interpretation of Solvita® Results for a Traditional Compost

The Index results simply by using the ammonia to compensate for the apparent CO_2—stability. High ammonia levels encountered in some composts can inhibit microbial activity or interfere in the CO_2 test. Also, ammonia by itself is dangerous for compost use on plants. As the Solvita® Ammonia test result number increases, the ammonia level in the waste decreases. As the carbon dioxide test result number increases, the carbon dioxide rate by the microbes decreases. Accordingly, the stability is measured by carbon dioxide respiration. A combination of both parameters indicates maturity—low carbon dioxide respiration and low remaining ammonia level. Table 7.8 provides a narrative description of the stage of the process of decomposition that the waste is within correlated with the maturity index number.

The highest level of curing of a compost is indicated with a Solvita® MI of 8 on the 1 to 8 point scale shown in Table 7.8. Whereas a low value of SOUR indicates a low remaining oxygen demand (the goal), a high value of MI (i.e., 8) indicates a well-cured compost with low remaining nitrogen due to reduced ammonia levels. Remaining organic matter will not necessarily be detected by this test and also, it will continue to exert an oxygen demand. As mentioned previously, the volatile solids concentration is the best indicator of organic matter.

Figure 7.9 shows a visual overview of the compost condition based on the two test results. As the waste matures from a raw waste to the finished stable mature product, it should advance from the bottom left to the top right as shown it Figure 7.11. Values to the upper left indicate potentially high C:N ratios and low pH and can result in a delay in maturity due to inadequate supply of nitrogen (a deficiency) or acidity. Carbon/nitrogen ratios greater than 35 are considered high from a composting standpoint. The lower right region represents potentially inhibited compost in a state of high nitrogen (a surplus) which can result in ammonia loss and delay of maturity due to high pH. Carbon/nitrogen ratios below 25 are considered low, again, from a composting standpoint. As implied a carbon/nitrogen ratio in the 25 to 35:1 ratio is ideal. For the Sonacala toilets, approximately half of the samples were found in the lower right region and approximately half in the desired area in the upper right corner (Figure 7.10). All of the fiberglass samples were in the lower right inhibited region. There was one sample between the ideal active and curing stages. The Solvita® MI values for these samples from the Sonacala toilets can be seen in Figure 7.11. Due to either high pH and/or too low or too high C/N, these results may well have been *false* maturity index values. They may have been inhibited samples. The inhibited nature of the desiccation toilet waste is one of the most clear results identified.

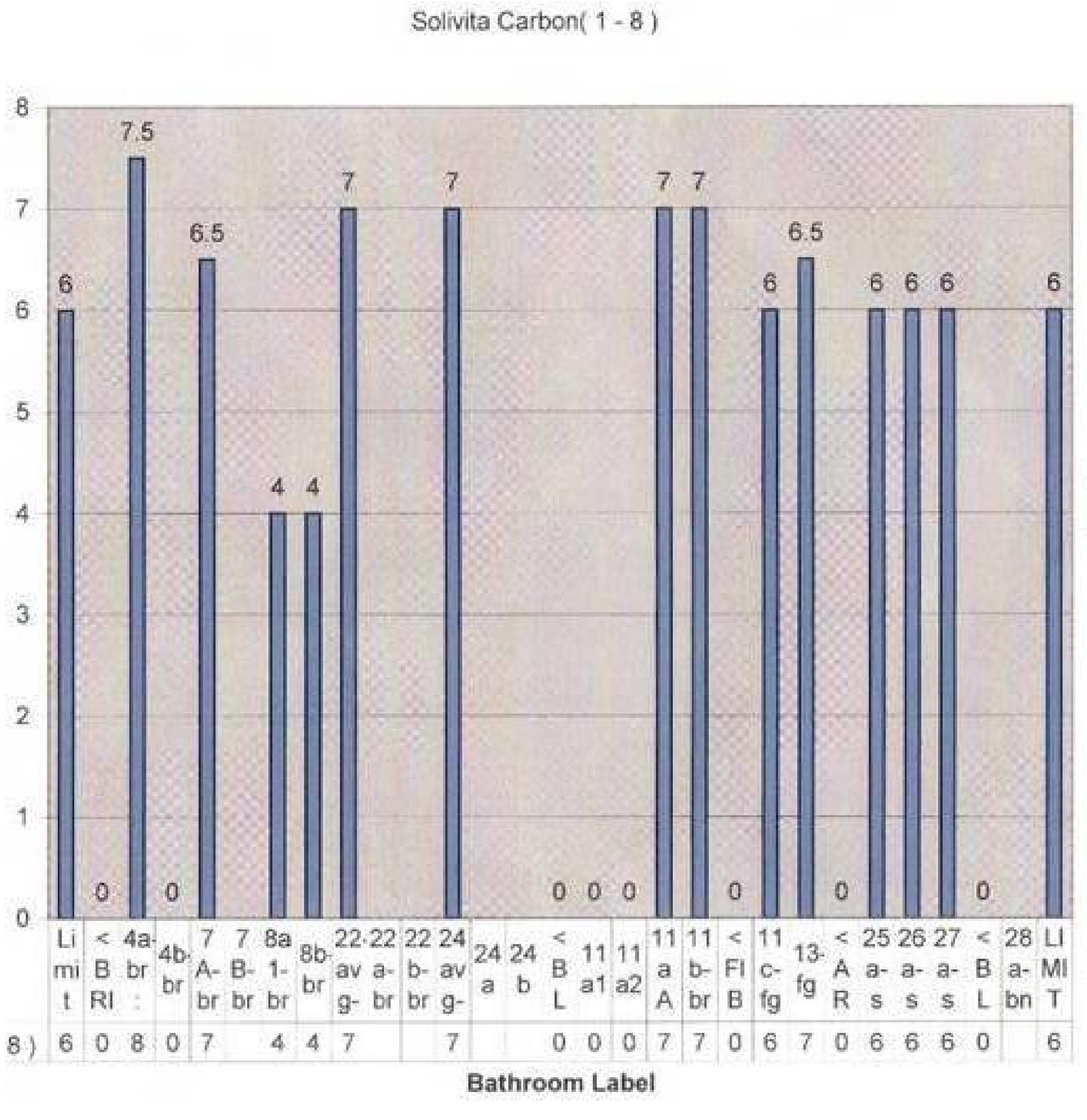

FIGURE 7.7 Solvita® Carbon Dioxide Kit Paddle Values for Sonacala Samples (a=top half of vault; b=bottom half of vault, br=brick, blk=block, fg=fiberglass)

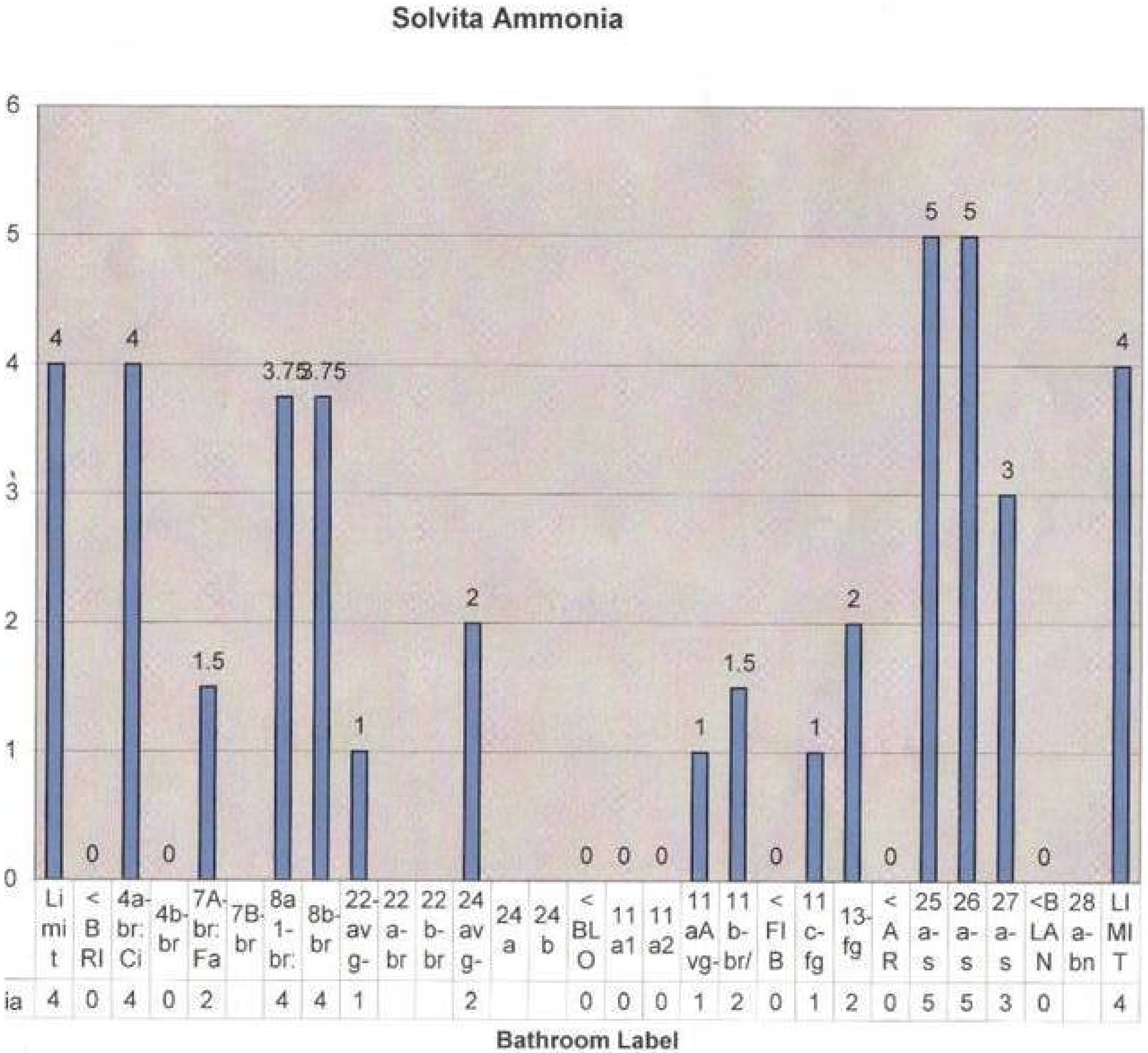

Figure 7.8 Ammonia Solvita® Kit Paddle Value for Sonacala Samples (a=top half of vault; b=bottom half of vault; br=brick, blk=block, fg=fiberglass)

7.3.11.6 Modification of Solvita Diagram for Desiccation Toilets

Since the waste in the desiccation toilet has much less water than ideal, less carbon, more nitrogen, and higher pH, the treatment path of the waste is very likely to not follow the diagonal ideal path in Figure 7.9. It would probably traverse a path at less than the 45 degree angle and totally negate the upper portion of the figure as a potential pathway for the waste. Different scenarios of other potential reduced effective areas, for other different pathways of the decomposition, are shown further below in Figure 7.12.

The following table shows a visual overview of your compost condition based on the two tests.

TABLE #2: Interpreting General Compost Condition with Solvita Ratings

use the A and C paddle color numbers and read across and down to where the columns meet

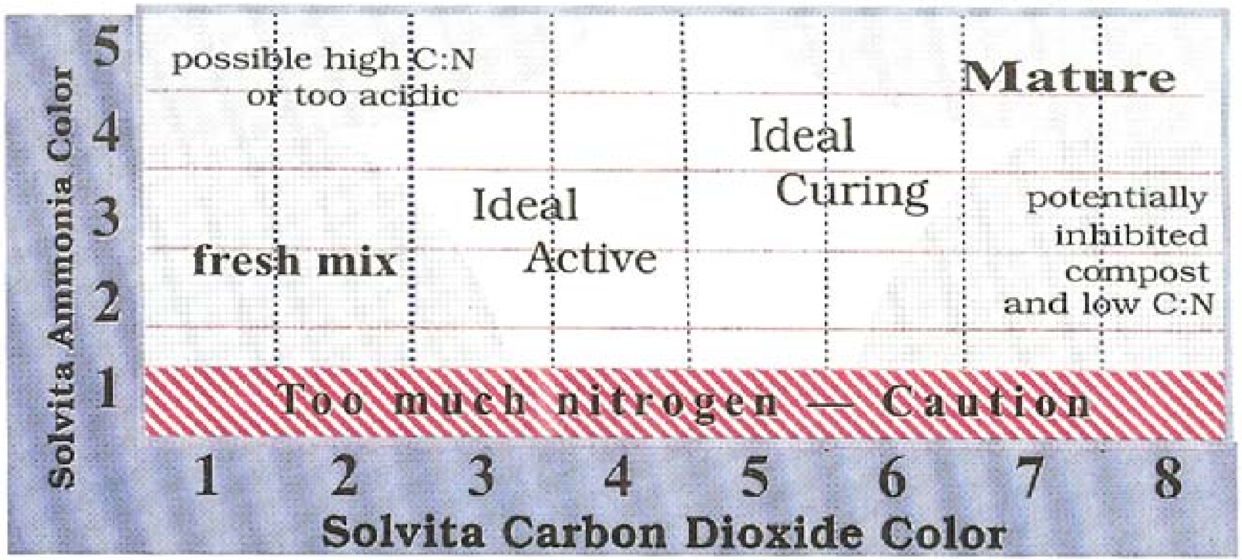

Figure 7.9 Interpreting General Compost Condition with Solvita® Ratings (Illustration by Woods End Research)

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The area in yellow is the effective area, the area in which potential decomposition states of the desiccation toilet waste and processes could exist. All of the area above the yellowed area (lower pH values) would no longer apply to potential states of decomposition of the alkaline waste. Consideration should be given if the non-highlighted areas should be totally eliminated from the illustration, with any necessary permission from Woods End Research Laboratory. Elimination of this area is not recommended at this time. If further research is done that would support these suppositions, however, the elimination of the area may be useful. There are advantages and disadvantages to eliminating the area. The disadvantage is that there may be desiccation toilets being operated in the more typical operational composting mode. As a result, the associated parameter values and this area would apply and accordingly be a necessary part of the illustration.

The disadvantage of keeping it included in the illustration is that it could mislead readers who believe the upper region is possible. Also it takes focus off the area where all or most of the activity occurs. An alternative is to cross-hatch the upper region (light diagonal lines). It should be noted that these potential modifications are based more on analysis of concepts than analysis of data points. The pH values for the different points did not match the areas very closely. Very few data points were available and they were from widely varying conditions. These figures have not been endorsed by Woods End Research Laboratory and any and all misinterpretations or inaccuracy are the sole responsibility of the author.

Again, **Figure 7.13** shows the value for the maturity index for the Sonacala samples.

7.3.11.7 Comparison with MI SOUR Equivalencies and Standards

In performing a comparative analysis of the Solvita maturity index parameter and the SOUR for a given waste, it is necessary to decide which units are most desired and most suitable for the SOUR parameter. The most common options are either based on volatile solids or based on total solids. Volatile solids are used because of concerns of potentially widely varying organic matter content between solids. The EPA has chosen to set the regulated values for SOUR on a per total solids basis. In the evaluation of the data set from Sonacala, the data reported and analyzed on a volatile solids basis did not yield logical conclusions. When the data was converted to a per total solids basis, the results appeared reasonable, from the standpoint of expected values and the treatment efficiency of the toilet of removing fecal coliform and an equivalent proficiency of reducing oxygen demand. The mean was within the regulated EPA parameter (treated adequately) and the mean with the standard deviation was reasonably close. On the per volatile solids basis, in comparison of the results to the Callegari center and Woods Ends Research Laboratory Solvita®/SOUR equivalency, the Sonacala data values were extremely high (under-treated). The decision was made to set standards based on the total solids units. This decision was not made in an effort to represent the toilet in a more favorable light; instead, represent it as appeared logically on what was believed about the process. Standards to considered, not to promulgate, based on the volatile solids unit basis, are discussed below.

The following table shows a visual overview of your compost condition based on two tests.

Interpreting General Compost Condition with Solvita™ Ratings

Use the A and C paddle color numbers and read across and down to where the columns meet.

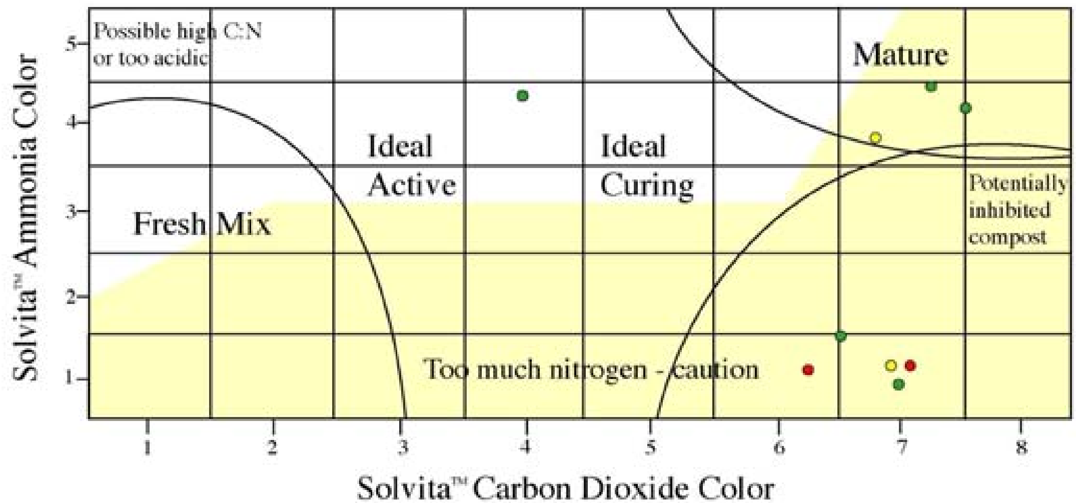

Figure 24. Potential Modification of Solvita™ Diagram (W.E.R.L.*): General Compost Condition-Alternative No. 4
(Area Based on Some Microbial Decomposition and Some Alkaline Inhibited Growth)

LEGEND
Green ● Brick Toilet Sample
Yellow ○ Block Toilet Sample
Red ● Fiberglass Toilet Sample

* Woods End Research Laboratory Table 2 Solvita™ Pamphlet, Version 3.5/2000

Figure 7.10 Interpreting General Compost Condition with Solvita® Ratings (Sonacala Samples)
(Source of original illustration by Woods End Research Laboratory; re-drawn and modified by Author)

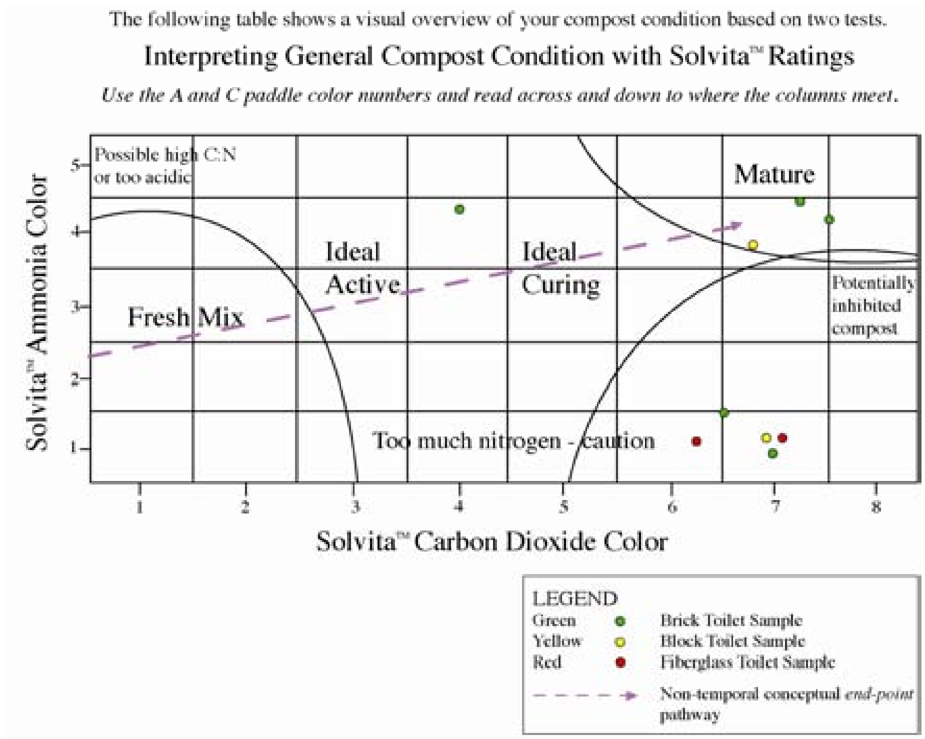

Figure 7.11 One Pathway of the Decomposition Process for a Typical Traditional Compost (Source of illustration by Woods End Research Laboratory; modified by Author)

Notes: (New Analysis not included in body of report):

1) Arrows represented conceptual points in time. These are not time-based pathways. They basically represent a hypothetical state of the compost at different points in time. The compost states would be at the actual endpoints of the arrowhead. The diagram does not imply or intend to represent that the location of the points along the shaft of the arrow are part of the analysis or states of the compost. The dashed arrow is intended to clarify that there is no meaning of the points along the shaft. Only the endpoints of the arrows (the arrowheads) have any meaning.
2) All points represent samples at the end of the decomposition process. The treatments for most of the samples were 3 to 6 years, with a few as low as one year.
3) Yellow area represents a portion of the Solvita® diagram where most sample points for the Mexican desiccation toilet data will never be located. This is because most samples have a high pH and low C/N ratio and thus are in the lower half of the diagram. Many, as can be seen, are in the lower right hand corner—the highly inhibited zone.
4) The location of the sample points in the upper-right region of the diagram imply that these are *mature* samples, that is, samples with no remaining carbon dioxide respiration potential and very low ammonium. That is not a correct assumption. Many samples analyzed had pHs above 8.5, which is higher than the allowed pH for correct use of the Solvita® kits. Analytical results of samples with these higher pHs may, or even do, provide *false* maturity state results.
5) Some samples may lay in the upper left region of the diagram, in this case the point at ammonia value of 4.3 and carbon dioxide value of 4. The presence of a point in this region implies that the pH is lower (more acidic than alkaline), C/N ratio is higher, and a more microbial degradation process (atypical) is occurring as opposed to an alkaline physio-chemical process (typical).

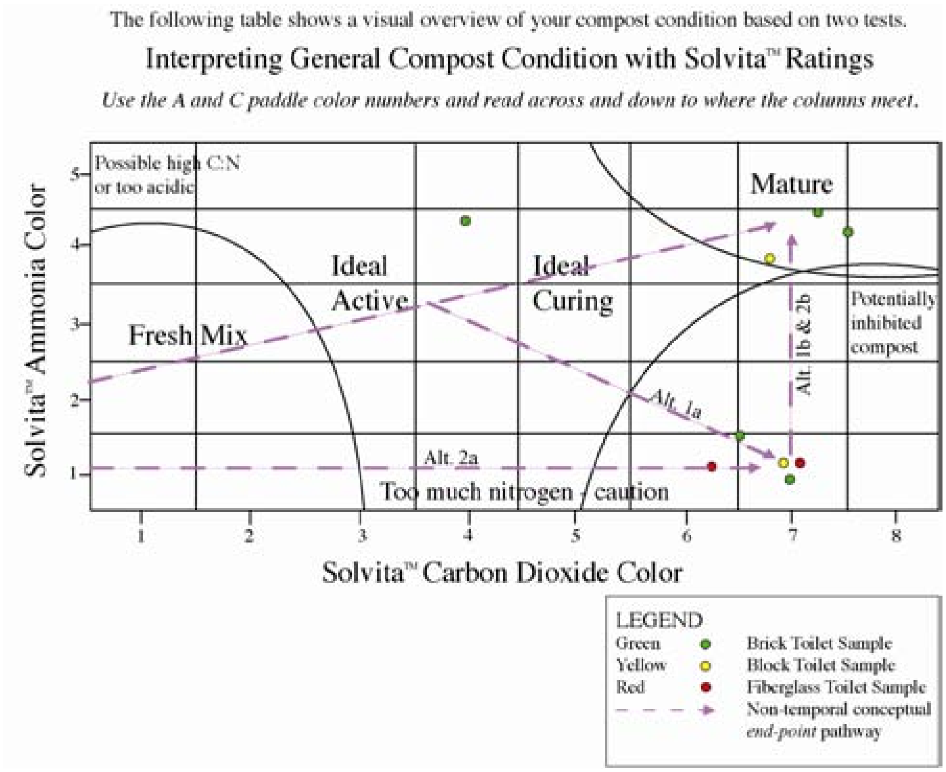

Figure 7.12 Potential Decomposition Pathways of Desiccation Toilet Waste
(Source of illustration by Woods End Research Laboratory; modified by Author)

Notes: (New Analysis not included in body of report):

1) Arrows represented conceptual points in time. These are not time-based pathways. They basically represent a hypothetical state of the compost at different points in time. The compost states would be at the actual endpoints of the arrowhead. The diagram does not imply or intend to represent that the location of the points along the shaft of the arrow are part of the analysis or states of the compost. The dashed arrow is intended to clarify that there is no meaning of the points along the shaft. Only the endpoints of the arrows (the arrowheads) have any meaning.
2) All points represent samples at the end of the decomposition process. The treatments for most of the samples were 3-6 years, with a few as low as approximately 1 year.
3) Yellow area represents a portion of the Solvita diagram where most sample points for the Mexican desiccation toilet data will never be located. This is because most samples are have a high pH and low C/N ratio and thus are in the lower half of the diagram. Many, as can be seen, are in the lower right hand corner – the highly inhibited zone.
4) The location of the sample points in the upper-right region of the diagram imply that these are mature samples — that is, samples with no remaining carbon dioxide respiration potential and very low ammonium. That is not a correct assumption. Many samples analyzed had pH's above 8.5, which is higher than the allowed pH for correct use of the Solvita® kits. Analytical results of samples with these higher pH's may, or even probably, provided false maturity state results.
5) Some samples may lie in the upper left region of the diagram, in this case, the point at approximately an ammonia value of 4.3 and carbon dioxide value of 4. The presence of a point in this region implies that the pH is lower (more acidic than alkaline), C/N ratio is higher, and a more microbial degradation process (atypical) is occurring as opposed to an alkaline physio-chemical process (typical).
6) The pathway with the star implies that ammonium is being released as the process switches from the degradation process to the alkaline desiccation process

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7.3.11.7.1 Considered Standard Based upon Volatile Solids

As mentioned above, the volatile solids analysis resulted in the finding that both the Solvita® SOUR equivalency standards and the Callegari standards (0.1 to 1.3 mg O_2 per g VS/day, respectively) were substantially higher (more strict) than the mean values of SOUR (5-day) found in the bottom half of the toilet vaults (8.4 ± sd 8.5) (see Table 7.11**)**. On the other hand, the concentrations found in the local soils of 11.7 ± sd 0.8 were basically higher than this mean. Additionally, the majority of the concentrations of the Sonacala bottom vault half samples fell in the 3.7 to 4.7 range. Understanding that it is believed that the average Sonacala toilets produced a reasonably-well to over-treated waste (based on fecal coliform counts and moisture levels), and furthermore that the local soil concentrations are higher, a standard of 4.0 mg O_2 per mg VS per hour appears to be reasonable based on the data set with the current understanding of the processes in the toilet. This standard would have to ignore a strict interpretation of the Solvita SOUR equivalencies. Based on one conversation with one practioner of Solvita® kits, use of compost with SOUR standards lower than the ideal Solvita® standards may be reasonable, if and only if, the desiccated waste is diluted with local soils prior to use. Based on local soils, use of desiccated waste with a SOUR value of 12.0 seems tolerable. Based on Callegari standards, a value of 1.5 would seen necessary. The standard of 4.0 mg oxygen per gram volatile solids per hour appears to be the most logical.

Table 7.11

Analysis of SOUR Based on Volatile Solids Unit Presentation

Parameter, Standard, or SOUR Condition Considered	Value (mg O_2 per g V.S. per hour)
Solvita® MI of 8 equivalency	0.1
Solvita® MI of 7	0.2
Lowest Callegari Value Observed	0.5
Highest Callegari Value Observed	1.3
Project Standard Based on Callegari, ignoring Solvita® Implied Standards	1.5
Lowest Value on Solvita® Scale <equivalent ammonia level as raw compost (not raw waste)>	1.7
Four of Seven Sonacala Samples (Bottom Half)	3.7 to 4.7
Established Standard	4.0
Sonacala Mean (Bottom Half of Toilets)	8.4 ± sd 8.5
Local Soils	11.7 ± sd 0.8
Potentially Tolerable Standard contingent of similar local soil values	12.0
Worst 2 Sonacala Samples	13.4 (for Toilet 8) 23.6 (for Toilet 11b)

Last of all, there are other reasons that a relaxing of the SOUR standards is reasonable and should put practioners at ease who are not accustomed to lightly ignoring standards. From the practitioner's perspective, if the grade of waste when removed appears not to be ready for use, it can be placed in a compost pile and managed there until it is ready. If it was considered ready enough, the application of this incompletely treated waste is acceptable because of the benefit of the high ammonia content in the material. The higher SOUR level may produce a potential positive crop response when applied correctly to heavy feeder field crops such as corn and sorghum. Because of the possibility of pathogens still existing in the waste (i.e., fecal coliform indicator), application of the desiccated waste is typically only recommended on *tall plants* such as these, and definitely not on vegetable and other lower lying plants. As mentioned earlier, the treatment of pathogens was adequate. In fact, considering that fecal coliform is probably the most critical criteria, and since those values were extremely low (most of them a factor of 40 lower than the EPA limit), a less strict SOUR and MI value is reasonable.

There is no validation in the literature for these adjustments; however, based upon the above analysis, the relaxing of the standards appears reasonable. Furthermore, a realistic understanding based on the perspective of the rural, developing environments similar to Sonacala must be maintained. More convincingly, these modified lowered standards of SOUR and MI value, as pointed out previously, are still significantly below the baseline concentrations found in the samples of the local soils. Last of all, also keep in mind that practitioners and users with definite goals of using the waste as compost for agricultural purposes would only benefit from the nutrient aspect of the waste with these lower SOUR and MI standards. In Guatemala, according to that study, it was that agricultural benefit that appeared to be a motivating factor in the use and acceptance of the toilets there.

7.3.11.7.1 Standard Based Upon Total Solids Basis

As mentioned above, the total solids analysis resulted in the finding that the values of the 5- and 10-day SOUR mean concentrations found in the bottom half of the toilet vaults of 1.1 ± sd 1.0 and 1.2 ± sd 0.4 mg oxygen per gram *total solids* per hour basis, respectively, were reasonable in comparison to the allowable EPA limit of 1.5. The mean values of 1.4 ± sd 1.1 and 1.6 ± sd 1.1 for the 5- and 10-day concentrations respectively of *all* the samples from both toilet vaults were also reasonably close to the 1.5 limit. Below in Table 7.12 is represented a comparison of the SOUR values. Five of the six concentrations of the samples removed from the bottom halves of the vaults were even lower with 5-day SOUR concentration levels of 0.3 to 0.7. Based on these samples, a minimum project standard of 0.5 is being set with an allowable maximum of 1.5 mg oxygen per gram total solids per hour—the EPA standard. The local soil mean concentration was 1.99 mg oxygen per gram TS per hour. The only significantly high sample was that of the most poorly operated toilet evident by its SOUR of 3.0 and 4.0 mg oxygen per gram total solids per hour (5- and 10-day concentrations).

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7.3.12 Metals

There were no heavy metal concentrations of concern or substantiality over allowable safe USEPA 503 regulation levels (2004), only sulfur was high; however, not excessively (see Appendix C). The concentration of the heavy metals in the individual toilets can be seen in Table 7.3. Other non-heavy metals, such as calcium, magnesium, and potassium (alkali metals) were analyzed also, of course with calcium being of most applicability as the element in quicklime. All calcium levels were high with a mean of 146,384 mg/kg ± sd 69,176. The required level of calcium as a micro-nutrient for agricultural purpose is between 26,000 to 54,000 mg/kg, so it was obvious that the calcium levels were excessive. These were also seen from the alkalinity calculations which demonstrated high levels of calcium carbonate equivalency (CCE) in some of the waste samples. The highest levels were in Toilets 4 and 11 (see Figure 7.14). This was suspected in Toilet 11 since there was a high use of lime there. The level of lime usage in Toilet 4 was uncertain. It was believed that there was heavy ash use in Toilet 4. As mentioned previously, the potassium content of 28,229 ppm of the finished sample from Toilet 4 confirmed the reported heavy usage of wood ash (from a wood-burning kitchen) and apparently a contributor to the success of that toilet.

Table 7.12

Analysis of SOUR Based on Total Solids (dry weight basis) Unit Presentation

Parameter, Standard, or SOUR Condition Considered	**Value<mg O_2 per g T.S. (DWB) per hour>**
Solvita equivalency	None(not expressed per TS)
Lowest Value observed by Callegari Center (unclear if TS)	0.1 (DWB)
Highest Value Observed by Callegari Center (unclear if TS)	0.3 (DWB)
Considered Project Minimum Standard; Based on Relaxing of Callegari Standard	0.5*
Five of the Six Sonacala Samples (Bottom Half) 5-day SOUR	0.3 to 0.7
Sonacala Mean for Bottom Half of Toilets (10-Day)	1.1 ± sd 1.0
Established Maximum Standard	1.5*
EPA Allowable Value	1.5
Sonacala Mean for All Vault Samples (10-Day)	1.6 ± sd 1.1
Local Soils	1.99
Worst Sonacala Sample (5- and 10-day) (Sample 8: Poorly Operated)	3.0 to 4.0

*These two values are established as the minimum and maximum standards for SOUR on a total solids basis.

7.3.13 Carbon/Nitrogen Ratio

For microbial growth, approximate values are 25:1 to 35:1. The mean value of the C/N ratio for the finished waste samples was 14.0 ± sd 6.1 which is significantly lower than this ideal level. Most of the values were in the 5:1 to 20:1 range (see Figure 7.15). According to the Solvita test kit literature (Woods End Research, 2000), carbon/nitrogen ratios less than 25 (a surplus of nitrogen) can result in ammonia loss and delay of maturity due to elevated pH. Carbon/nitrogen ratios greater than 35 (a deficiency of nitrogen) can result in a delay in maturity due to inadequate supply of nitrogen.

Since the desiccation process does not depend on C/N ratio as does a composting process, from the treatment standpoint, these values were not considered detrimental. Other parameters monitored to measure nitrogen were SOUR and Solvita. Carbon was also measured with Solvita and extensive discussion in that section concerning the effect of low or high C/N ratios on treatment and the characteristics of the waste.

As far as baseline values, one of the three soil samples with a C/N ratio of 0.63 obviously indicates very high nitrogen content. Since there are free-roaming animals, the soil sample could likely be contaminated with animal excrement, of course high in nitrogen. Addition of a soil with high nitrogen could have influenced the C/N ratio of the waste samples, particularly if the waste sample collection was closer to the time of closing of the vaults. The other two soil samples had C/N ratio values of 8.4 and 9.5. This indicates that the local soils would benefit from a desiccated waste that had some higher levels of nitrogen. The mean percent nitrogen in the samples was 0.9 ± sd 0.5 and the mean percent carbon was 10.1 ± sd 1.7.

7.3.14 Salts

The salts that are of interest are sodium and potassium (a salt is any ionic compound, such as sodium). Sodium levels were all lower than the allowable safe level of 4,500 mg/kg with its mean at 3,433 mg/kg ± sd 979.6. From an agricultural and compost standpoint that is an important result (see Figure 7.16). High salt content is often a significant concern and limiting factor in agricultural soils. Since salt content is a factor that can adversely affect plant growth, it was beneficial that most toilets had values lower than the limit. The mean sodium content of the soils were 212.3 mg/kg ± sd 14.5, substantially below the allowable levels.

Potassium, as a salt, must be limited also, however, it is a micro-nutrient so a minimum level is required for plant growth. As mentioned previously, the mean potassium levels were acceptable, with a mean of 18,070 mg/kg ± sd 5192 right at the EPA limit of 17,000 mg/kg. The potassium levels were higher for Toilet 4—ash 28,000 to 29,000 range.

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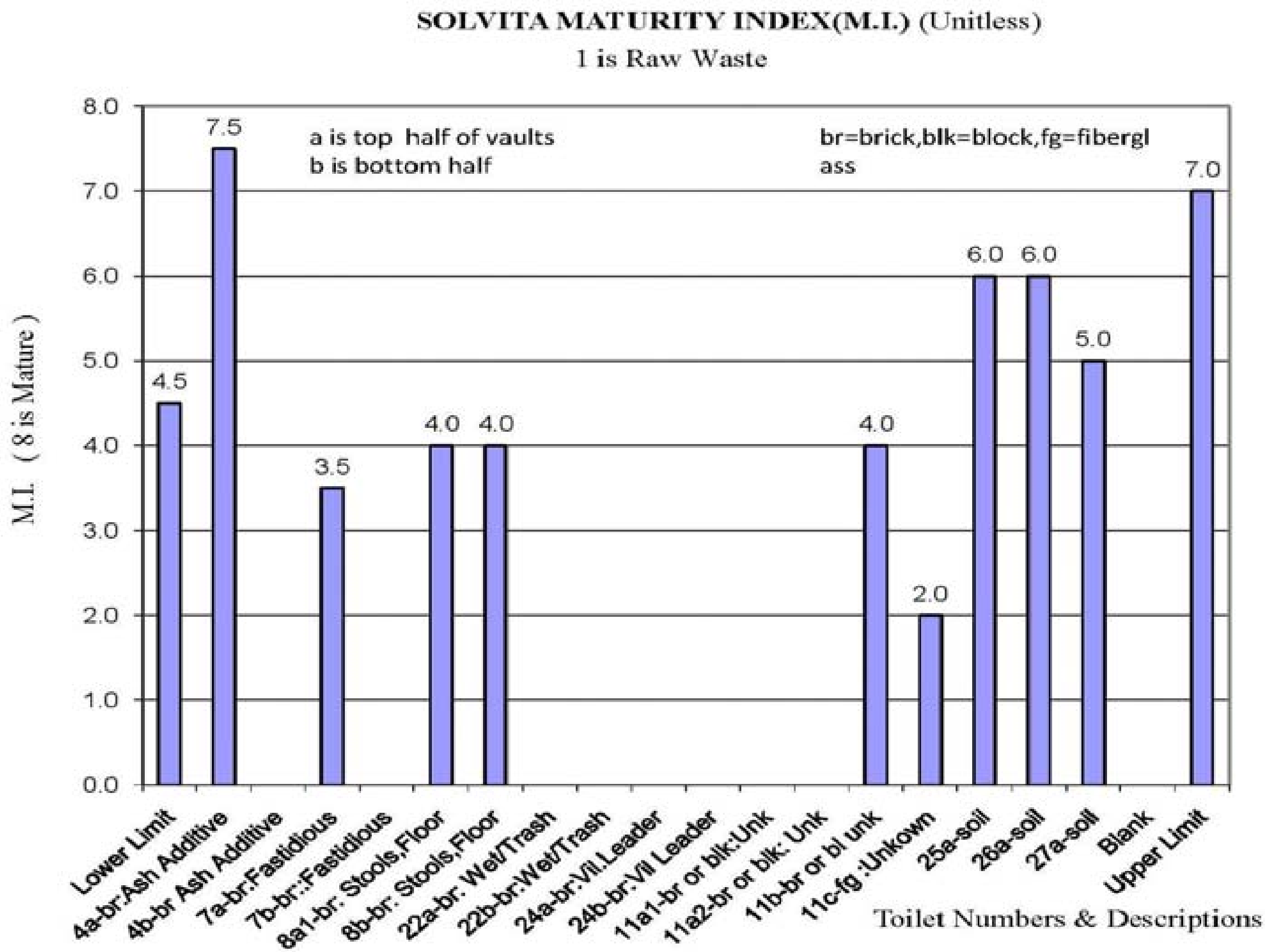

Figure 7.13 Solvita® Maturity Index (1 is Raw) (a=top half of vault; b=bottom half of vault)

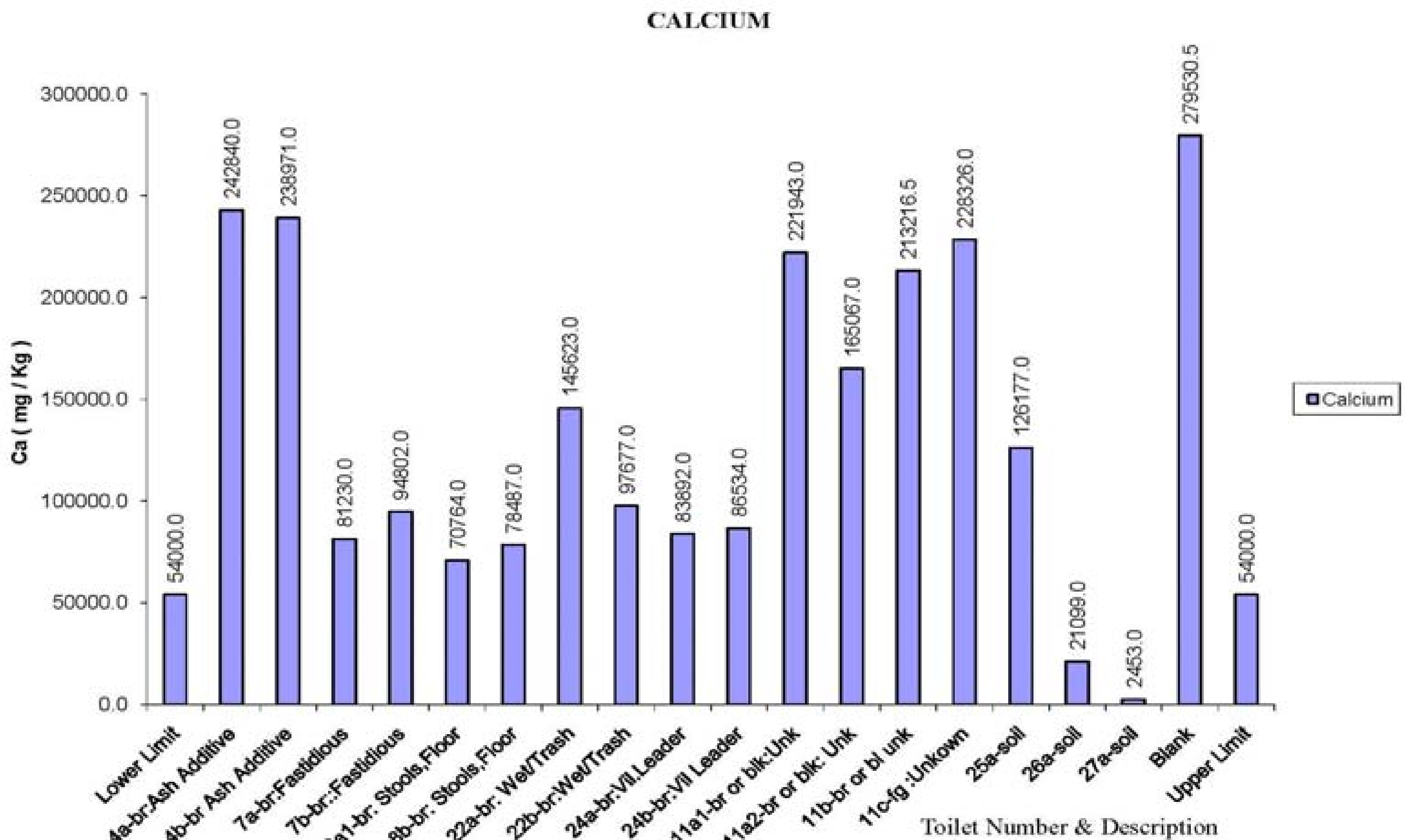

Figure 7.14 Calcium (a=top half of vault; b=bottom half of vault)

7.3.15 Phosphorus, Potassium, and Nitrogen

Maximum regulatory limits for phosphorus, potassium, and nitrogen (PKN) were viewed as limits desirable to maximize. In other words, the limit is basically indicating that above that amount, there is a potential environmental impact, therefore the limit cannot be surpassed. From the agricultural standpoint, the closer to that value the better for the purpose of providing these necessary nutrients to the soil.

The mean value for phosphorous (P), the first macro-nutrient required by soils, was 11,678 ppm ± sd 3323 which was significantly below the minimum regulatory allowable limit of 32,000 ppm (see Figure 7.17). That concentration was only 36.5 percent (11,508/32,000) of the desired allowable limit (see Table 7.13).

An example calculation of the complete analysis and mass balance procedure performed on a sample from a toilet prior to the investigation can be found in Appendix D**.** That is an example calculation of the limitation on the application rate of the desiccated material to a specific soil based on the desiccated materials' specific pH and alkalinity. Note that the sample in that example had a pH of 8.0 very close to the Sonacala mean pH of 8.1. The analysis showed that it was the alkalinity, not the pH that was the limiting factor, which is explained further below. In that calculation, the sample analyzed was labeled MSS5 standing for Mexican sludge sample. Although that sample was from a toilet in Sonacala, that toilet was not from any of the families interviewed in 2002. It was collected and analyzed separately in 1999.

The phosphorus concentration in the MSS5 sample was 1,928 ppm (mg/kg), substantially lower than the Sonacala mean of 11,678 ppm ± sd 3323. This comparison of the Sonacala mean results, with the example calculation, demonstrates that each toilet's waste would have to have a mass balance performed to know its specific application rate. Most municipalities in the United States have agricultural extension services which provide free analysis and consultation services to homeowners and farmers for this type of analysis. As far as the Sonacala mean of 11,678 mg/kg phosphorus compared to the allowable limit of 32,000 mg/kg, this made the Sonacala finished waste only a moderate source of the soil's agricultural needs.

As far as the levels of potassium (K), the second macro-nutrient required in soils, those levels were between 12,000 to 30,000 ppm range with a mean value of 18,070 mg/kg ± sd 5,192. This mean value was right at the regulatory allowable limit of 17,000 (see Figure 7.18), only exceeding it an insignificant amount. This concentration of the average toilet desiccated waste an excellent source of nutrients for this macro-nutrient, meeting 106 percent of its need (see Table 7.13). This mean concentration was higher than the concentration of phosphorus in the MSS5 sample (177 mg/kg) in the Appendix 4 example calculation**,** by a factor of 102, that is, in percent format**—**10,209 percent. This indicates that while the MSS5 sample was very low in potassium, hence not exceeding EPA limits, the mean Sonacala samples were an excellent source of potassium, and close to exceeding the allowable EPA limit.

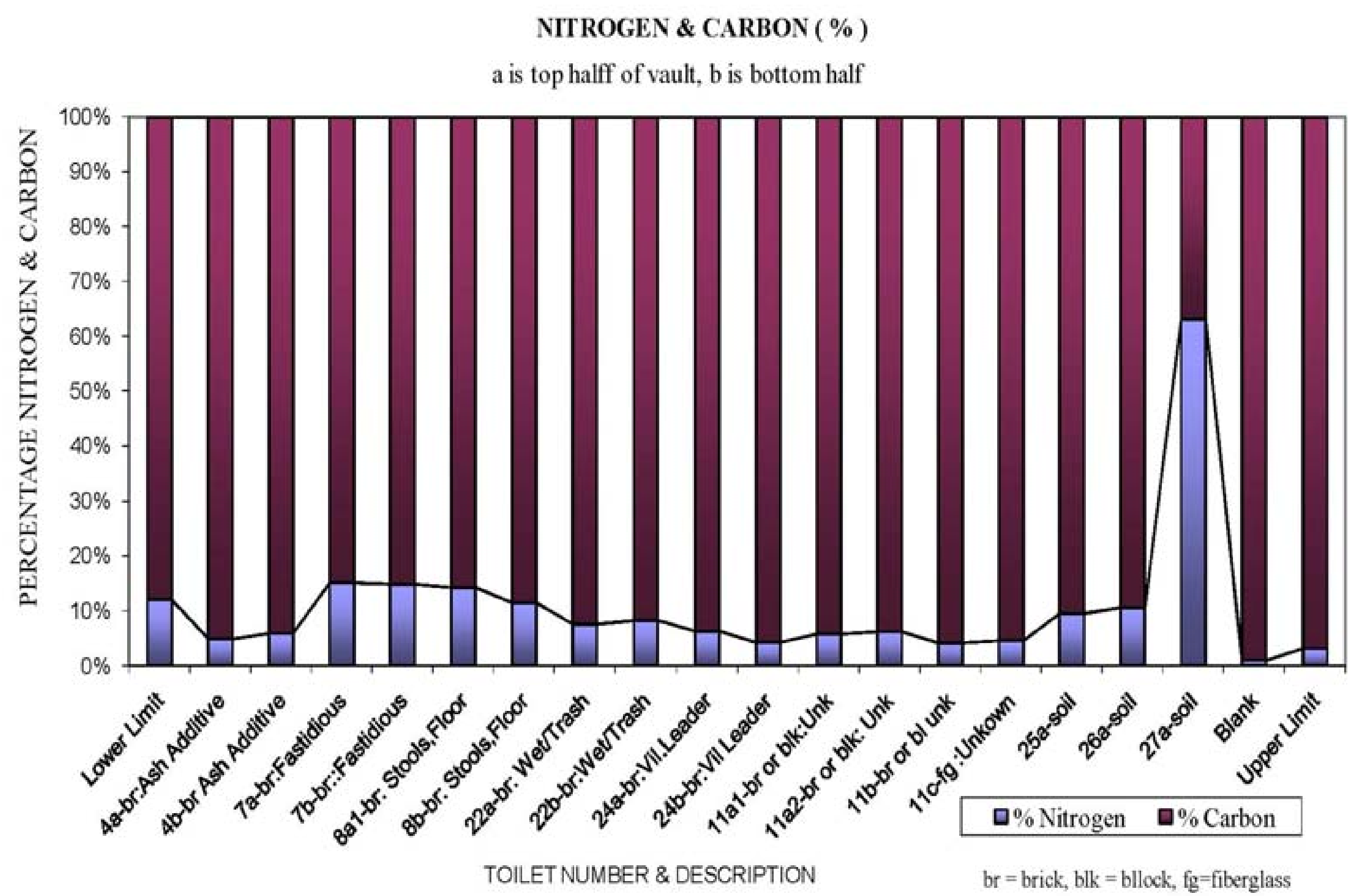

Figure 7.15 Carbon/Nitrogen (C/N) Ratio (a=top half of vault; b=bottom half of vault)

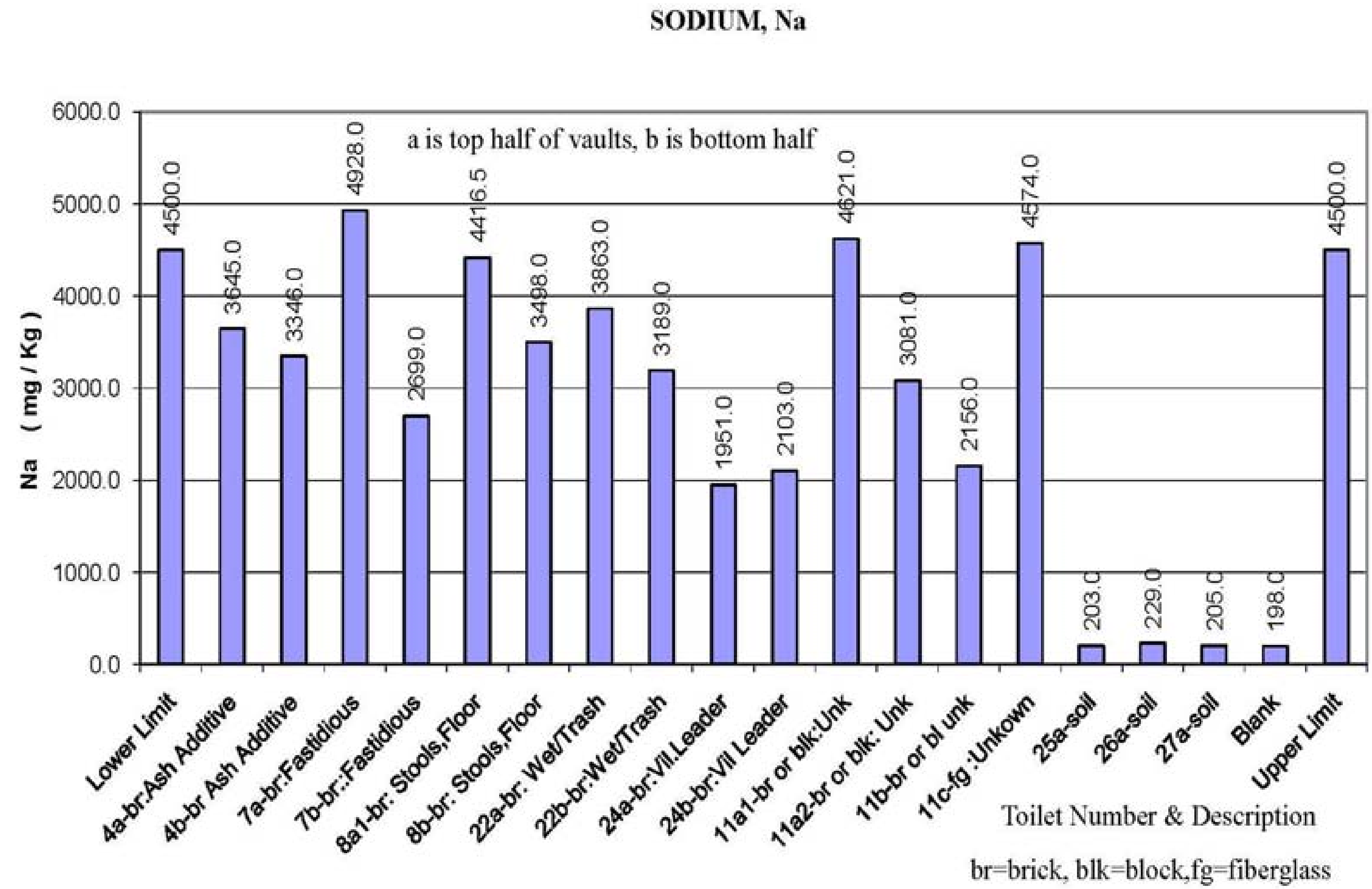

Figure 7.16 Sodium (a=top half of vault; b=bottom half of vault)

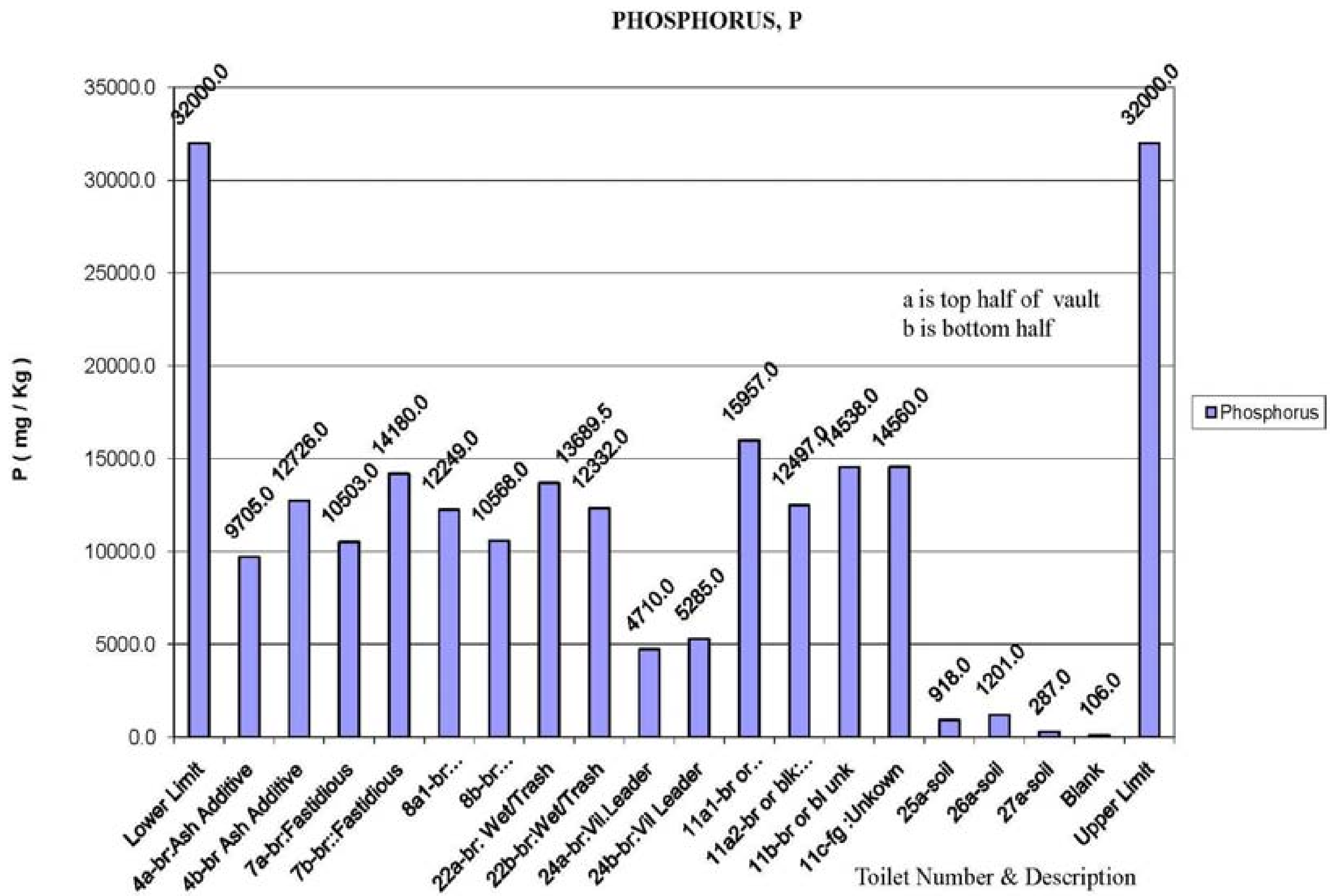

Figure 7.17 Phosphorus (a=top half of vault; b=bottom half of vault)

Finally, of upmost importance, the last and most critical macronutrient for plant growth—nitrogen—had a mean value of 0.9 ± sd 0.5 in the Sonacala desiccated waste samples. This mean concentration was below the minimum typical concentration rate of 1.0 percent (90 percent of that value) and much further below the maximum typical concentration of 2.6 percent (only 34.6 percent of that value) (see Table 7.13). Typical concentrations were reported by the Callegari Environmental Center (Schillinger, 2002)

In summary, the percent met of the agricultural needs for plants is shown below, considering undiluted application of the desiccated material to the soil, not considering any other limitant factors.

Table 7.13

Phosphorus, Potassium, and Nitrogen Waste Concentrations, Limits, and Needs

Element	Mean Value in Sonacala Waste (Compost)	Allowable Desired Limit	Percent Fertilizer Need Met[1]	Actual Ratio[2]
N	9,000 mg/kg ± sd 500 (0.9 % DW ± sd 0.5)	10,000–26,000 mg/kg (1.0–2.6%)[3]	34.6 – 90.0%	1
P	11,678 mg/kg ± sd 3323	32,000 mg/kg	36.5%	1.2
K	18,070 mg/kg ± sd 5191	17,000 mg/kg	106.3%	1.8

Table Notes:
1. This does not consider any other limitants requiring dilution of the soil.
2. As can be seen the ideal PKN ratio was not obtained, which is another indicator that the waste is not a true compost amendment.
3. These reported desired nitrogen concentrations are based upon nitrogen results from laboratory tests through a procedure with no acid pretreatment. In procedures where there is acid treatment, the allowable range is at a higher concentration of 1.2 to 4.0 percent. All the values of nitrogen reported above are on a percent dry weight basis.

Concentrations of these nutrients in the local soils had mean values for phosphorus of 802 mg/kg ± sd 467.9 (desired concentration of 32,000), for potassium of 2209.0 mg/kg ± sd 1856.5 (desired concentration of 17,000), and for nitrogen of 1.0 ± sd 0.5 (desired concentration of 1.0 to 2.6 percent) (see Table 7.14 below**)**. This indicates that the local soils did not meet minimum macro-nutrient requirements for agricultural purposes; therefore the above concentrations of the macro-nutrients in the desiccated waste would be beneficial to the local soils. As a result, it was concluded that although the desiccated waste did not meet all of the soils' agricultural requirements, it did meet some of them. According to multiple sources (Schillinger, 2002 and Hall, 2008), compost should not be used as a nutrient source, or at least not as the sole source. It appears its main purpose is as soil amendment for its organic matter value, which retains water and can also be a source of benefical microbial organisms that serve an important role in plant growth processes.

Table 7.14

Phosphorus, Potassium, and Nitrogen Soil Concentrations and Limits

Element	Mean Value in Local Soils	Range in Local Soils	Desired Concentration
P	802 mg/kg ± sd 468	287–1201 mg/kg	32,000 mg/kg
K	2209.0 mg/kg ± sd 1856	241–3929 mg/kg	17,000 mg/kg
N	1.0 % ± sd 0.5 dry weight	0.4–1.33%	1.0–2.6%

The actual application rates allowed of the desiccated material in the local soil would be determined and possibly reduced by other limitant elements. In the MSS5 sample, it was shown that alkalinity was the limitant factor and therefore reduced the application rate and resulted in more modest contributions by the desiccated waste to the agricultural needs of the local soils. The percentage that the agricultural needs were met by the MSS5 sample is shown in Table 7.15 below.

Table 7.15

Percentage Phosphorus, Potassium, and Nitrogen Requirement Met

Element	Percentage of Fertilizer Requirement Met
P	18.5
K	4.3
N	38.3

7.4 Limits of Data

Because of the limited number of actual bathrooms sampled and other reasons, this analysis had its limits. There were less than 30 samples total (the ideal minimum sample set) and various independent factors, so isolation of cause and effect to any one parameter was difficult. Furthermore, the large majority of the data obtained was from the brick toilets. According to a former Callegari Environmental Center staff member there was not enough data to make any statistically-based conclusions, however, trends could be examined(see Appendix E). Appendix F is a preliminary draft summary of Appendix E. Regardless, some logical trends were seen and the data from the other two desiccation toilet projects confirmed the basic results of the work.

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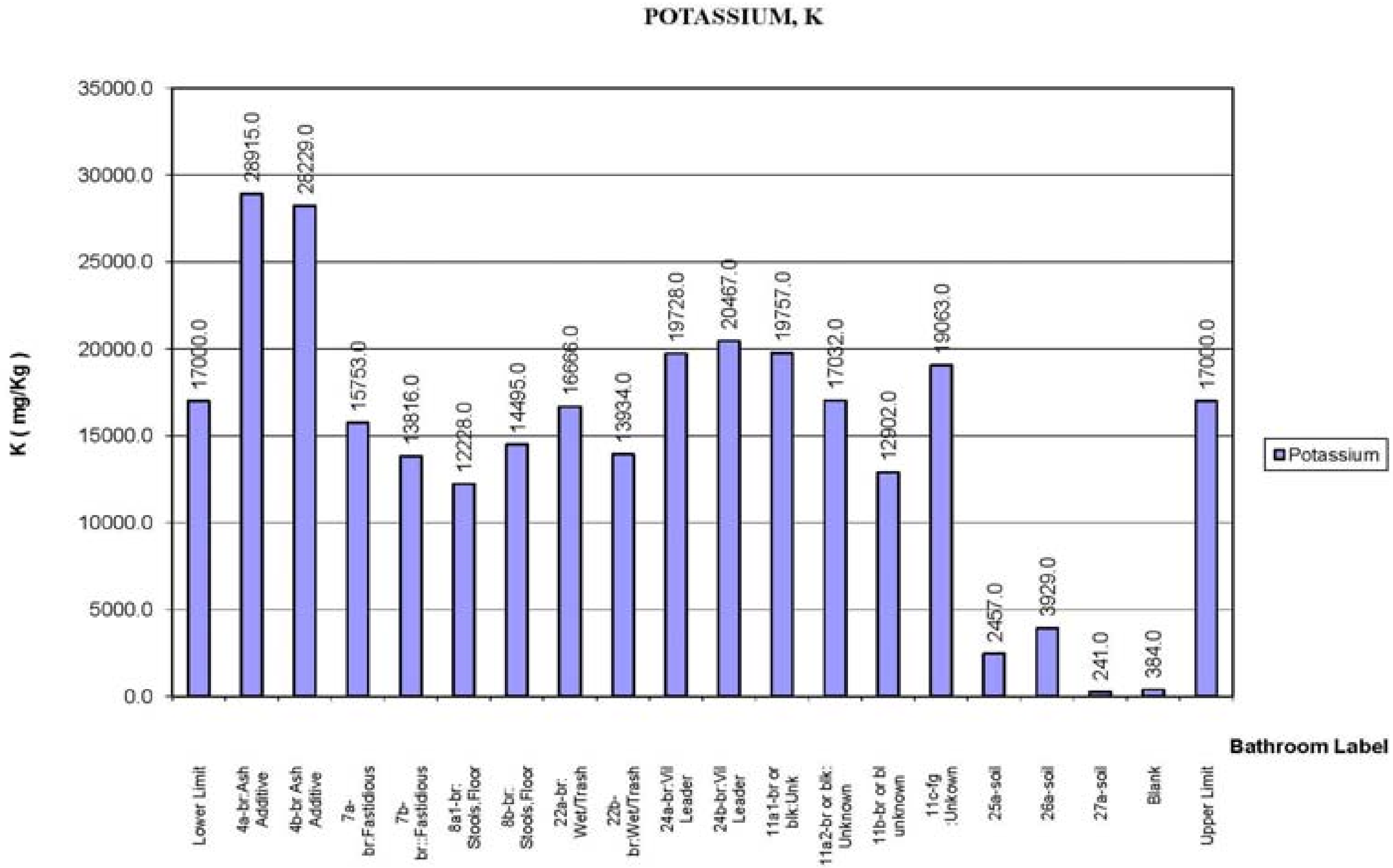

Figure 7.18 Potassium (a=top half of vault; b=bottom half of vault)

7.5 Associated Resulting Adverse Conditions

When the treatment process works well, there is very little, if any, adverse condition associated with the waste. When not maintained there can be insects, airborne dust, and odors.

7.5.1 Insects

Insects, particularly mosquitoes, flies, and worms, were the most predominant ones of concern. Obviously, flies and mosquitoes are a nuisance to the user and health hazard by potentially transmitting pathogenic organisms found in the waste, where the insects would lay eggs or come in contact with the waste surface.

In one period in the community, an infestation of flies or mosquitoes was reported in some of the desiccation toilets, whose cause was not identified. This apparently caused a decrease in the prestige of these toilets and the long-term social acceptance, or immediate rejection. It is believed that users sometimes tolerated these problems, however, it left them with the desire to only use the desiccation toilets as an intermittent solution until a more favorable option (the waterborne toilet) became feasible for them.

In communities where the desiccation toilet does not have a bad reputation or stigma, insects and other potential problems (not definitive ones) are better managed and not problematic. In the Guatemala project, these problems were minimal as can be seen in the statistics shown in **Appendix G**.

7.5.2 Airborne Contaminated Dust

In the dry season, for example in the Yucatan peninsula of Mexico, there were reports of individuals becoming ill up to seven times a year with gastrointestinal diseases that were transmitted by wind when dust-like dried excrement would become airborne. This was reported in the case where individuals were indiscriminately defecating in the field and the stools were exposed on the surface. In the desiccation toilets, this is not so much a concern under proper operation, but it is possible for partially treated dry unstable waste dumped in the environment, or exposed waste from the fiberglass bins.

7.5.3 Odors

Odors were the other large factor affecting the acceptability of the toilets. The process by which odors are produced was described above. The greater the quantity of excrement introduced to the toilet, the more ammonium and ammonia produced, the source of odors. If corresponding higher quantities of additive, especially lime, and increased leveling does not occur, odor and insect problems will result. Accordingly, if you solve the odor problem, you mostly solve the insect problem. Instead of odor being a reason to reject the toilet, with proper education it can

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become an indicator that the user is not operating the toilet in the proper way and maintenance or a change in operation or design is needed.

7.6 Desiccated Material Use Restrictions

To safeguard against any possible harm from resistant microbes, some recommend that the desiccated material is only recommended for ornamental plants or fodder crops and two months prior to planting (Bates and Roy, 1984). Users of the toilets in Guatemala applied the finished waste to crops including corn, broccoli, and coffee, with good results (see Appendix H).

Although some toilets have produced very good results, the characterization of the desiccated material not only as a compost, but also as a waste, should be considered. As such, it is recommended that the desiccated waste (or desiccated material) be used and/or disposed of properly. As discussed, USEPA (2004) and others have strict requirements and limits on disposal and/or use of treated wastewater sludge. Although these regulations may not be able, there should be guidelines for the use and/or disposal of the final end product.

The standards that have been set for all the parameters above have been compiled in Table 7.16. The parameters that can be measured in the field for a moderately-rapid assessment are shown in Table 7.17. These are the project standards being promulgated for the quality of the final desiccated compost product. From the perspective of the rural development practicioner, the level of treatment that is achieved in these toilets, if operated properly, is very high, and any amount of resistant microbes would normally be exponentially lower than most other sanitation options and existing practices in similar rural settings as Sonacala. Pit latrines monitored in the Guatemalan project showed considerably lower levels of treatment than the Guatemalan desiccation toilet. Fecal coliform levels were approximately 2,000 MPN (Xet, 1988). Waste from pour flush toilets, septic tanks, and gravity sewer systems used in this region appeared to have little to no treatment. From that perspective, the main restriction should be to not use the desiccated material on any vegetable plants or plants with low-lying fruit. Regardless, caution is recommended here in bypassing well-established standards, particularly in the early stages of the development of this technology in the scientific and academic circles. In order to be fair to both viewpoints, the final product could be referred to as a desiccated waste with some agricultural value. To demonstrate a neutral stance, the end product could be referred to as “desiccated material.” The parameters of pH and moisture are critical in assessing the nature of the final end product from the desiccation toilet.

Table 7.16

Pertinent Recommended Laboratory and Field Technical Standards

#	Technical Parameter	Recommended Standard
1	Intermittent pH of waste in Active Vault	≥10.00 (@ 11, 100% NH_3)
2	pH of finished desiccated waste (compost)	8.75–9.25 or above if desired
3	Alkalinity (% Calcium Carbonate Equivalent)	Expected high alkalinity values overcome by dilution of finished waste with local soils or thin application rates; some rates observed as low as 1/10”
4	Waste Temperature	No recommended values; finished waste temperatures observed 63–68 F
5	Ambient Temperature	No recommended values; 90–95 degrees F known to be suitable
6	Average Period of Repose of Each Vault	0.75–1.0 year (0.5 ok if managed well)
7	Average Treatment Period of Each Vault	Approx. 1.1 to 1.5 years (0.75 ok)
8	Approximate Size of Each Vault; Approximate Max. Volume of Each Vault Possible Volume Reduction	0.8 m high x 1.3 m deep x 0.85 m wide; Approx. 0.9 m^3 (approx. 32 ft^3); Volume reduction by 50% possibly ok
9	Water Content in Active Vault Contents	Perhaps 25–35 % ≤ 20% prevents most microbial growth
10	Water Content in Finished Waste	15–20% (as low as 5–10% observed)
11	Fecal Coliform	1000 MPN/gram TS (DWB)
12	Other Pathogenic Indicators	As required by specific project
13	Volatile Solids (VS)	10–20% or > if used as soil amendment
14	Maximum Specific Oxygen Uptake Rate (SOUR) on Volatile Solids Basis	1.5 to 4.0 mg O_2/g VS/hr; <Equal to 36 to 96 mg O_2 /g VS/day>
15	Min and Max Specific Oxygen Uptake Rate (SOUR) on Total Solids Basis (DWB)	0.5 to 1.5 mg O_2/g TS(DWB)/hr
16	Minimum Solvita Maturity Index (if compost managed properly)	5.5 or possibly lower based on SOUR approach and if composting not a goal)
17	Metals	USEPA 501(c)3
18	Carbon/Nitrogen Ratio	25:1 to 35:1
19	Salts	Sodium: 2500–4500 mg/kg; Potassium: 6600 mg/kg min
20	PKN (EPA limits)	P: 32,000 mg/kg max; K:17,000 mg/kg max
21	Nitrogen	1.0%
22	PKN	*Very approximate ratio of* factors of 1 to 2 between different parameters, i.e. 10:10:10, or 10:10:20.
22	Insects, Odors, Waste Visibility, and Handling	As tolerable by user

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Table 7.17
Moderately-Rapid Assessment with Most Pertinent Field Technical Standards

Table #	Technical Parameter	Recommended Standard
1	Intermittent pH of waste in Active Vault	≥10.00 (@ 11, 100% NH_3)
2	pH of finished desiccated waste (compost)	8.75–9.25 or above if desired
3	Alkalinity (% Calcium Carbonate Equivilent)	Dilute waste with local soils; Thin application rates or apply as local agronomist recommends
4	Ambient Temperature	No recommended values; warm, drier environments are most suitable
5	Average Period of Repose of Each Vault	0.75–1.0 year (0.5 ok if managed well)
6	Average Treatment Period of Each Vault	Approx. 1.1 to 1.5 years (0.75 ok)
7	Approximate Size of Each Vault; Approximate Max. Volume of Each Vault Possible Volume Reduction	0.8 m high x 1.3 m deep x 0.85 m wide); Approx. 0.9 m^3 (approx. 32 ft^3); Volume reduction by 50% possibly ok
8	Water Content in Vault Contents during Operation (% of Total Weight)	Perhaps 25–35 % ok; ≤ 20% prevents most microbial growth
9	Water Content Recommended in Finished Waste (% of Total Weight)	15–20% (5–10% observed); squeezing waste sample with paper towel should not moisten towel
10	Fecal Coliform (MPN)	Use fecal coliform test kit (≤1000 MPN)
11	Minimum Solvita Maturity Index (if compost managed properly)	5.5 (Possibly lower)
12	Salts	If concerns, check w/ local agronomist
13	Insects, Odors, Waste Visibility, and Handling	As tolerable and desired by user
14	Additive Use	Generous enough amount after *every* use in order to *completely cover* waste
15	Additive Type	Mix: lots of Lime; some Ash; some Soil

CHAPTER 8. OTHER ANALYSIS AND DISCUSSION

8.1 Design Life

The design life of the toilets is considered to be 10 to 15 years. If once every several years, any necessary sections of the outside of the vaults and shelter are re-floated (troweled with a mixture of cement, fine sand, and water), there should be no other significant rehabilitation. The durability of the inside walls of the vaults exposed to the waste are probably a limiting factor in the life of the toilet. Very little inspection of the interior was possible. In some regions of the United States, real estate statistics show that families move every 3 to 5 years, maybe 7, on the average. Furthermore, since individual preferences and capacities to move to other technologies changes over time, life spans of 5 to 10 years may be more realistic. There were several families that selected and implemented new technologies after around 10 years.

8.2 Individual Family Facility

Several homes had desiccation toilets that were built by the previous owner and not used by the current owner. Considering the phobias and personal hygiene values, it is very understandable why a new homeowner would not want to use a sanitation facility used by another family. Desiccation toilets have been shown to only be successful on an individual family home basis. Communal facilities, such as public restrooms, public parks, and multi-family dwellings have not been successful applications of this technology.

8.3 Advantages and Disadvantages of Brick, Block, and Fiberglass Toilet Versions

Each of the toilet types was unique. The fiberglass toilets were the least preferred and the highest in cost, to the municipality who purchased them. All three are discussed below.

8.3.1 Brick Toilets

The brick toilets were drastically overdesigned—vaults being too big, the detention time too long, pathogen reduction much higher than necessary, nutrient reduction higher than beneficial—and resulted in developmental technical staff not being able to be present in the community to assist when some of these toilet cycles ended. Toilet vaults became caskets into which the waste was entombed and never retrieved and reused.

8.3.2 Block Toilets

Block toilets had most of the same advantages and disadvantages as the brick toilet. Additionally, the concrete block material had more of a professional look and had some beneficial construction features.

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8.3.3 Fiberglass Toilets

An advantage of the fiberglass toilets is that the entire shelter, chamber, and bins are completely portable. Accordingly, the shelter can be moved around to different locations of the site to find the correct combination of satisfaction of the users' and toilets' need for privacy from neighbors and pedestrians, proximity to home, shade for shelter comfort, and sunlight to promote desiccation. Of course, the shelters were too hot and appeared to have significant odors.

8.4 Benefit/Cost Analysis of Needs and Wants

The values and beliefs of individuals in respect to their "needs and wants" are very personal. A benefit-cost analysis is needed to attempt to assess if the user's investment of time, money, energy, et cetera for the construction of a toilet is more valuable to them than other needs and wants that they have. They do make that evaluation.

Privacy, convenience, comfort, prestige, and social status are other factors that users appear to want and need. Those factors that sometimes, if not always, are more a key motivating factor for an individual to implement a desiccation toilet, as opposed to concerns about health (Anorve, 1988) and environmental protection. Health and environmental protection are most often the goals of the developmental organization supporting the project. These are not necessarily the goals of the individuals and the community.

An attitude of predestination was implied in many discussions with individuals. With that philosophy, an individual's health would be considered in the hands of God, not a desiccation bathroom. As far as personal environmental beliefs and standards, there exist different attitudes and beliefs amongst individuals in all societies. One key individual (who had and continues to have a desiccation toilet after 14 years) desired to switch to a waterborne toilet, which would discharge, without treatment, directly to a canal. When asked by the investigation team about the adverse pollution aspect of his desire to use that technology, his response was that he felt that environmental protection was the responsibility of the government. This was the belief and attitude of an individual that worked closely with the non-profit group for over ten years.

8.4.1 Other Benefits of Sanitation and Water Supply

Besides direct health benefits through the reduction of disease (see Appendices I and J), many other benefits that water and sanitation provide have been identified (see Appendix K). Some of those benefits are improved primary health care, improvements in nutritional status, improved services to health centers, clinics, and schools, time released for women, household irrigation and animal watering, promotion of commercial activity, and improved quality of life. Also a link between water supply and sanitation programs has been found, in that one program and improvement is dependent on the other. Specifically with water projects, they have been shown to have financial viability, in that they have the potential to earn revenue sufficient to operate and maintain the facilities and often to generate a return on capital (Okun, 1987).

8.5 Changing Demographics, Attitudes, and Rejection

The demographics of this community have changed significantly over the time span of the technologies' presence in the village. Previously there were mostly long-term inhabitants in the village. More recently there has been an influx from Mexico City, bringing different values. The values of these city dwellers from one of the biggest metropolises in the world are believed to have changed the acceptability and scrutiny of the technology. There may exist more criticism and less tolerance of poorly maintained toilets, and less community cohesion. These individuals, frustrated with the overwhelming pollution of Mexico City, have "come to the country" to escape the big city's problems, and probably do not want to be exposed to what they perceive as a technology that is contaminating their new environment. The concept of "flushing waste away" is very predominant in Mexico, especially in the cities, in that once you push the lever, the waste is discharged, goes downstream, is "out of sight and out of mind," and more importantly out of the community and their backyard. Not only these new habitants, but it appears plenty of long-standing households also perceive the technology as rustic and primitive, and because of modernism and "their fear of their waste, they prefer the option of putting distance between themselves and their waste" (Robert, 1988).

When the developmental group was in the community in the late 1980s and 1990s, there appeared, at least on the surface, a warmer feeling, more acceptance, more respect for individual desires and choices. Request for toilets were coming in, new construction was occurring and the toilets were "still fresh and clean"—the technology and project was on the upswing. Even though the effort was never really a "community project" it appeared to have an implicit acceptance. By the mid- to late 1990s, the honeymoon stage of the project was over. As toilets matured, aesthetics lessened and more problems arose, with less outside help, acceptance dropped and toilets started to fail. The project was on the downfall and the technologies' reputation had been damaged.

8.6 Percentage Coverage of the Community

The three different technologies were all introduced at different times. Twenty to twenty five brick toilets were introduced in the late 1980s by the developmental group. Not long after, the local municipality paid for the construction of more toilets—perhaps another twenty. Originally there was approximately 60 families, then increased to from 90 to 100. Coverage was fluctuating between 30 to 50 percent. Later, perhaps 30 of the fiberglass versions were brought in and completely installed by outsiders. Anywhere from 20 to 40 block toilets were supported by an environmental branch of the state. With the migration of individuals into the community, most assumed not to participate, the coverage with desiccation toilets then went down. The number of households at the time of the investigation was well over 100, perhaps upward of 150. The number of desiccation toilets in operation is unknown — a guess is that it is probably 15 to 40. Coverage then would be at maybe 5 to 20 percent. The level of the community with sanitation service is one method to gauge the success of projects. Accordingly, from a coverage standpoint, the project was inadequate, and could even be considered a failure.

8.7 The New Sanitation Questions

As far as more positive perspectives, instead of a failure, the results can be considered a limited success. There were very positive results at individual households and new toilets continue to be built. As the water shortage gets more critical, acceptance and coverage could well increase. It appears now the question on some community members mind is not whether the technology works, but instead which one of the three desiccation toilets works better. Villagers started to do a comparative analysis. Also, there are fewer households with the practice of indiscriminate defecation in the field. This traditional habit was more possible when community population density was less. Now, with more people moving in and the neighbors next door being more critical, indiscriminate defecation is less feasible, not only from "peer pressure" but also from the standpoint that the individual desire for privacy with this act is less possible with the increased population. Indiscriminate defecation is not only not acceptable to the neighbors, but neither is it to the individual. The issue was no longer whether the villager would continue with his practice of indiscriminate defecation, but instead, as indicated above, which type of sanitation facility he would like to construct and use—the waterborne toilet or one of the three desiccation bathroom models. A new choice had to be made.

Figure 8.1 depicts the multi-technology competitive nature of the three new technologies. Even at one household, sometimes one family would have two or three different models for different reasons. Family 4 had a brick toilet then received a fiberglass toilet because they won it in a community raffle (it was a left-over from the fiberglass program). They used the extra one (the fiberglass version) for the children. This toilet with higher temperatures and odors probably made this model less acceptable to the children, and perhaps was maintained in a less hygienic state and more disorderly since the children may not maintain it as well as the mother.

Other families had multiple ones because when block and brick promoters came through the community they were convinced the newly-introduced model was a better one, or it was perhaps pushed or semi-forced on them (probably more by the fiberglass vendor). Often families took advantage of multiple models to have a *his and her* model. Sometimes there were two of the same model because the family had built another one when they had the financial resources to do so (that personal investment showed a real ownership and belief in the technology in general and that model in particular). In both cases (Families 15 and 24) the new models were built to have a model closer to the home, for convenience. That showed that the family overcame any initial fears of the waste and odors, perhaps wanted more privacy, did not want to have to wander out so far at night, did not want to encounter animals, particularly scorpions, or was afraid to trip and fall over a rock. In several cases the desiccation toilets were abandoned and a water toilet was built because it was their desire to have something more modern (Family 6) and easier for the children (Family 22).

It should be noted that the existing waterborne pour-flush technology in rural settings like Sonacala does not have the same fully-modern status as its counterpart in more economically well-to-do urban households. Figure 8.2 depicts this more rustic version of the pour flush toilet. The desiccation toilet can be and has been built with a high level of modernity inside homes of all economic classes and geographic areas and neighborhoods, with all the *bells and whistles* of a ceramic water toilet (see Figure 8.3 (a) Upgraded wall tile and & ornamentals, (b) Preferred local *culturally-attractive* colors and upgraded steps). These are cost-prohibitive for most users.

Figure 8.1 Three Competing Alkaline Desiccation Compost Toilets (Left to right: Fiberglass, Block, and Brick Versions) (Photograph by Joel Roberts)

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A

B

Figure 8.2 Pour-Flush Water Toilets (A: Outdoor, B: Indoor) (Photograph by Joel Roberts)

The provision of choices, or alternatives, is what the appropriate technology movement is all about. An alternative technology had been introduced to the community and now the inhabitants were beginning to view it and choose it as a viable alternative.

In addition to the desiccation toilet, other technologies should perhaps have been introduced. Introduction of only one toilet type when it is obvious that other models were preferred is potentially an imposition or, at best, ignoring the local desire that should have been addressed and allowed to play out. Appendix L is a good illustration of what happened (and could happen) in cases where a community's interest is ignored. That is, abandonment of the imposed technology and substitution of the technology desired by the community.

As mentioned above, quantitative coverage of the community was low and could be seen as a failure. More optimistically, it could be considered a limited success. The introduction of a new, low-cost, moderate-maintenance, more-or-less appropriate technological option did occur and was accomplished. Qualitatively the project did appear to be a success.

Availability of water, actual physical ability to construct, cost, and privacy will be dominating factors influencing the ultimate decision of each family. Continuance of status quo is no longer an option—change is almost a certainty. With all these factors in mind, households will have to choose between the water closet and the desiccation vault.

8.8 Linkage Between Sanitation Engineering and Rural Anthropology of Sonacala

There were various links found between the engineering and the anthropological aspects of this work. The first link was the need to establish a numerical system that allowed the joint analysis of both the engineering and the social factors. The ASH/VS ten-based ratio was discovered which has a lot of potential significance as an educational tool.

The quantification of relative values of social and technical factors and development of a logical means to place weight, importance, and rank on factors in decisionmaking was one of, if not the most important, linkage established. That product included the elaboration of two tables (one technical one social) for approximately 12 to 18 of the families visited.

The next linkage found was the dual need for technical support and personal reassurance to assist users in their adoption of the desiccation toilet. Underlying emotional elements were discovered as the prime deterrents for successful implementation, use, and acceptance. Suspicion of outsiders and newly-introduced technology seen as experimental, anxiety as related to change, and a lack of knowledge and experience with the technology were some of the social factors influencing adoption of the technology. Technical factors such as odor, insects, visibility of waste, fear of possible contamination within the waste, and the disagreeable aspect of waste handling were some of the technical factors impeding adoption of the technology and its use.

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It was determined that small pilot projects, working on an individual-family basis, were the most successful means to implement the technology. Incorporation of user feedback to modify the technology and the program were determined to be critical in the process of adoption.

A

B

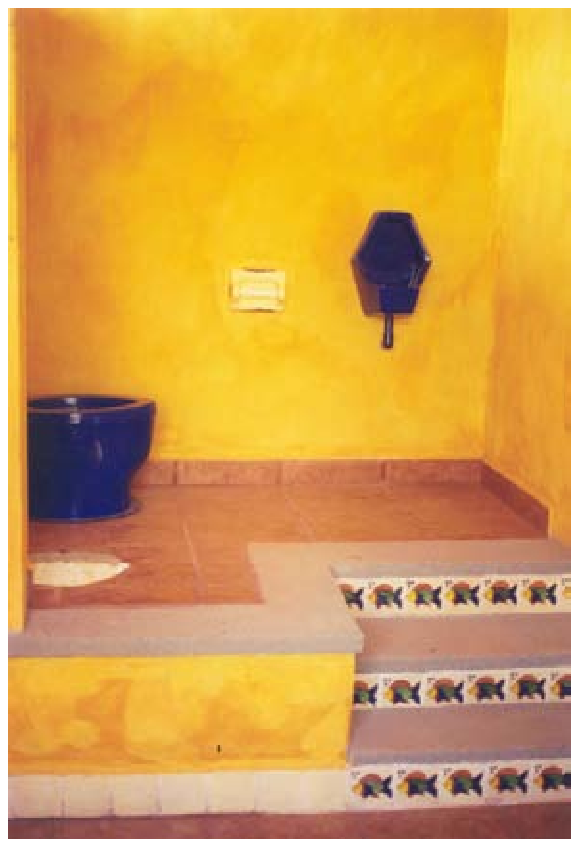

Figure 8.3 Indoor Version of an Upgraded Desiccation Toilet (Atypical for Rural Areas) (Photograph by Cesar Anorve)

CHAPTER 9. MODERATELY-RAPID ASSESMENT TOOLS

Several tools were developed to aid the field worker in assisting the user with the assessment of his experience. The first assessment tool is shown in Figure 9.1. The dots in this diagram are filled in with the villager as they discuss his experience. It consists of seven stages:

1) Initiation and Use of the Desiccation Toilet
2) Problems Encountered by the User
3) Maintenance Required of the User
4) Completion of a Vault Cycle(s) and End Use of Waste/Compost
5) Benefits Realized by the User
6) Cost Incurred by the User, and
7) Final Evaluation of the Toilet

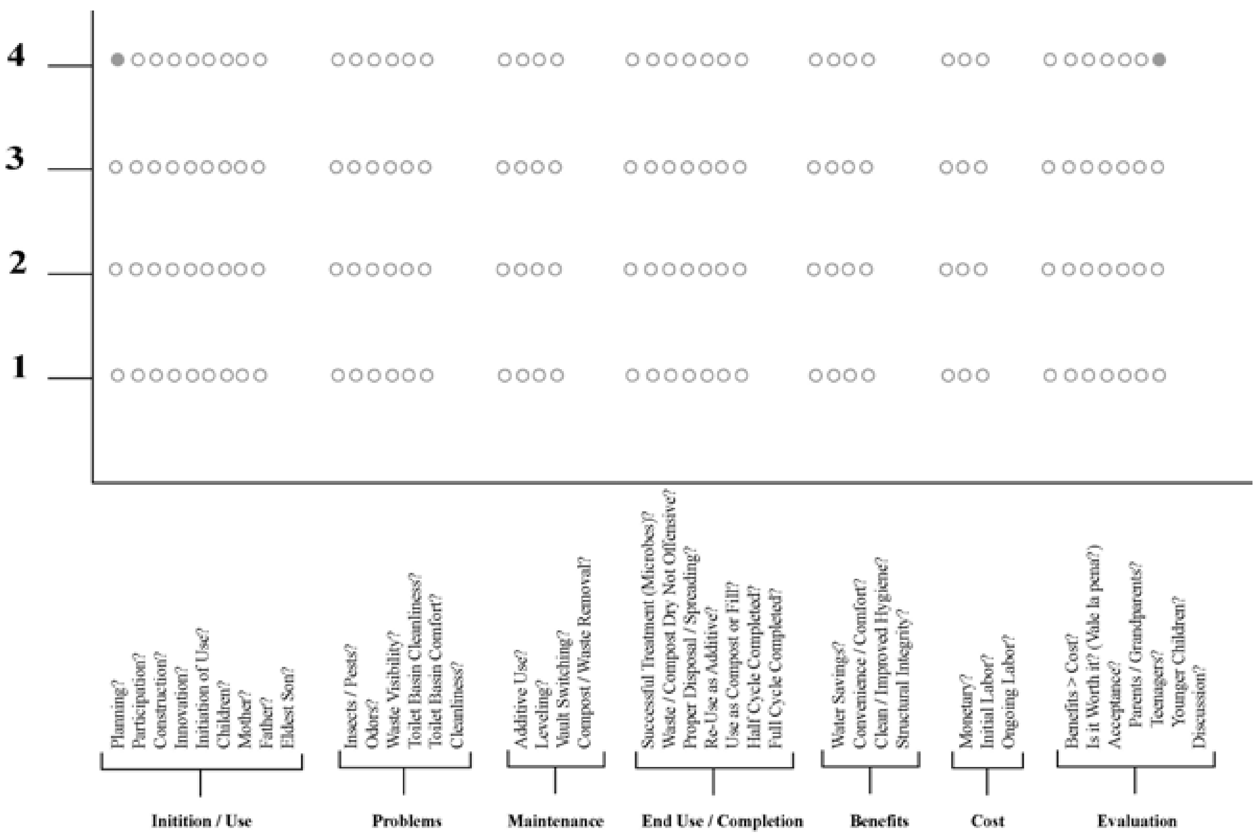

Figure 9.1 Moderately-Rapid Assessment Connect-the-Dots Worksheet

Each section consists of various sub-steps that the user may have encountered and also various parameters that may have affected his acceptance of the toilet and the toilet's success.

The diagram is filled out simply by using each one of the items as a talking point and asking the user to rate each parameter on a scale of 1 to 4 (see Figure 9.2).

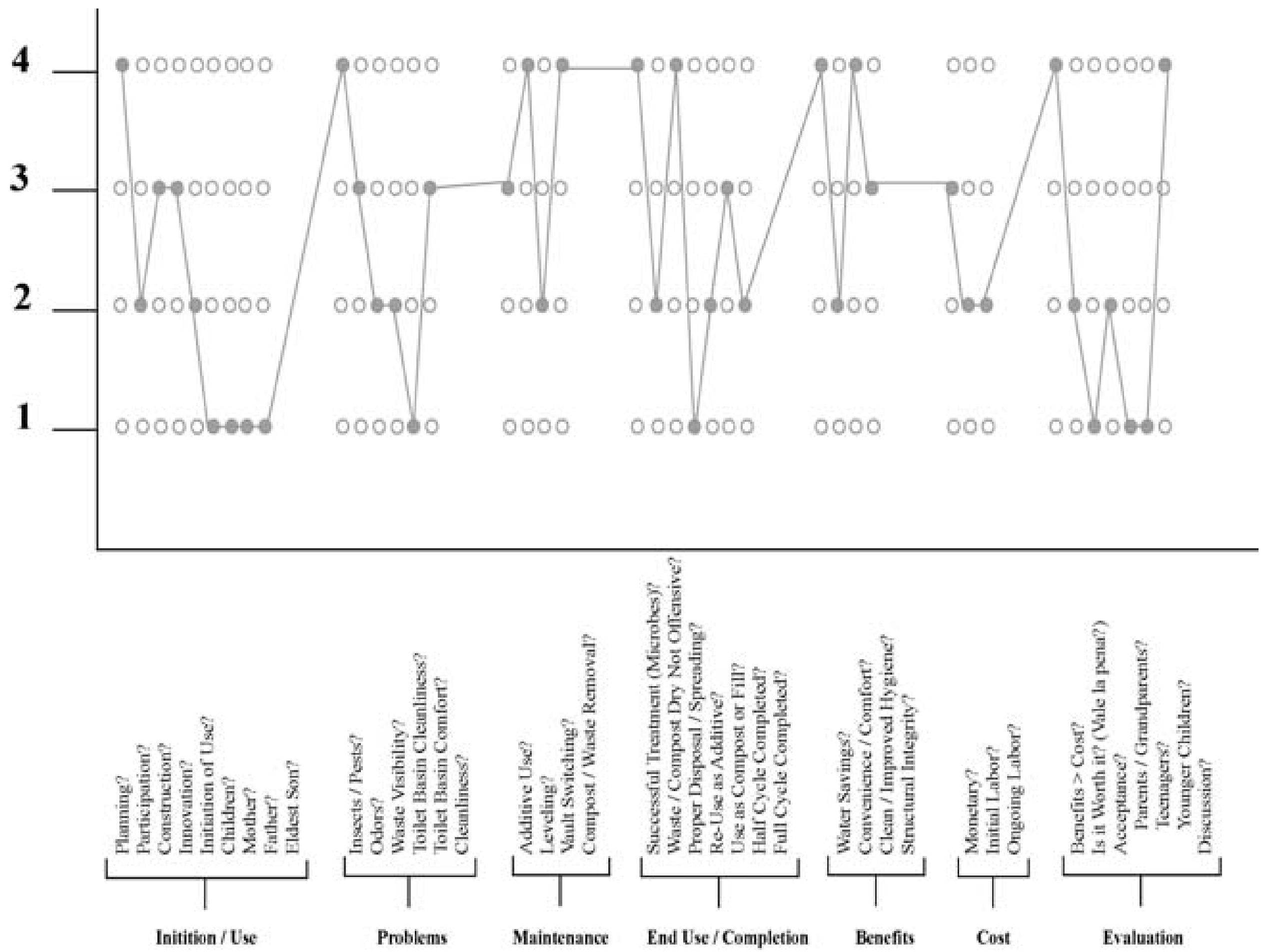

Figure 9.2 Sample Moderately-Rapid Assessment Connect-the-Dots Worksheet

The significance of the 1, 2, 3, and 4 values could be decided by the user and/or the community. The user or the technician simply darkens in the circle that most applies to the user's experience. The first parameter (planning) and last (discussion) are pre-filled as values of 4 since anyone participating at any level has completed those two steps. Rating them as a four is also a positive way to start out the discussion and a positive way to end it. The following classification of these values could be used in the absence of any others:

1) Step not initiated, or serious problems encountered with stated parameter
   (Possible Social Rejection and/or Possible Technical Failure)
2) Step started but not completed; significant problems encountered but toilet still in use
3) Step almost complete or completed; very little problems encountered
4) Step completed; no problems encountered
   (Definite Success and/or Definite Acceptance)

This tool assists in quantifying the user's qualitative experience and doing a simple graph of the results. For the final part of the exercise, the dots are connected resulting in a straight-line graph. These steps and factors are more-or-less in chronological order as the user would experience them. Accordingly, a review of the diagram would show the peaks and valleys of the experience of the user. The visualization should assist the user in making a realistic evaluation of his experience and turn that experience into useful feedback to the technician and to make modifications to the technology or his own operation and maintenance habits.

The graphical comparison to the peaks of a mountain (success and acceptance)—a rating of 4—and the trough in a valley (success and rejection)—a rating of 1 or 0 (not filled in), was designed to enable the user's experience and evaluation of that experience to be analogous to a concept that the user can relate to—a mountainous terrain. The four-based system is used because it is simple and easy to make decisions with (4 is a definite success, 3 is a moderate success, 2 is a limited success or limited failure, and 1 is a definite failure). One to four was also used because that is the numerical system for the humoral system adopted in Latin America. These diagrams and ratings can be modified by the technician and/or the user to suit their experience. The important point here is the exercise of *connecting the dots* between the stages and factors of a person's experience with their desiccation toilet.

Another tool that the technician can use in assisting the user and evaluating his experience is shown is Figure 9.3. It incorporates the concept of a feedback circle. As the user experiences the various parameters shown in the diagram, those experiences become part of a feedback cycle that converts this user experience to know-how, confidence in decision-making and analysis of the user's next step, and knowledge on how to improve the technology and operation and maintenance. In the appendix, there is a summary of the technical and social parameters input and output in the form of a *block* diagram based on the concept of input equals output.

The technical standards established in Chapter 7 for the desiccation toilet are instrumental in determining, from a scientific standpoint, the success of the toilet. Caution should be exercised in strict use of these standards since the science is more complex than the standards presented and individuals view this technology from vantage points other than health and science. Regardless, the key standards are presented and are instrumental in evaluating the technology. They are shown below in Table 9.1 which is a summarized version of Tables 7.16 and 7.17.

Figure 9.5 below is a helpful illustration to the technician of the different parts of the desiccation toilet and how it is assembled. The desiccation toilets in Sonacala were similar to this drawing, with the combined vault dimensions being 1.70 meters wide by 1.30 meters deep and 0.80 meters high. This illustration is very useful in explaining the physical configuration of the toilet, the steps of construction, and also an explanation of the scientific principals and their relation to health protection. This type of hands-on practical discussion of a health-related issue is much more meaningful and acceptable to the user than approaches resembling classroom-type

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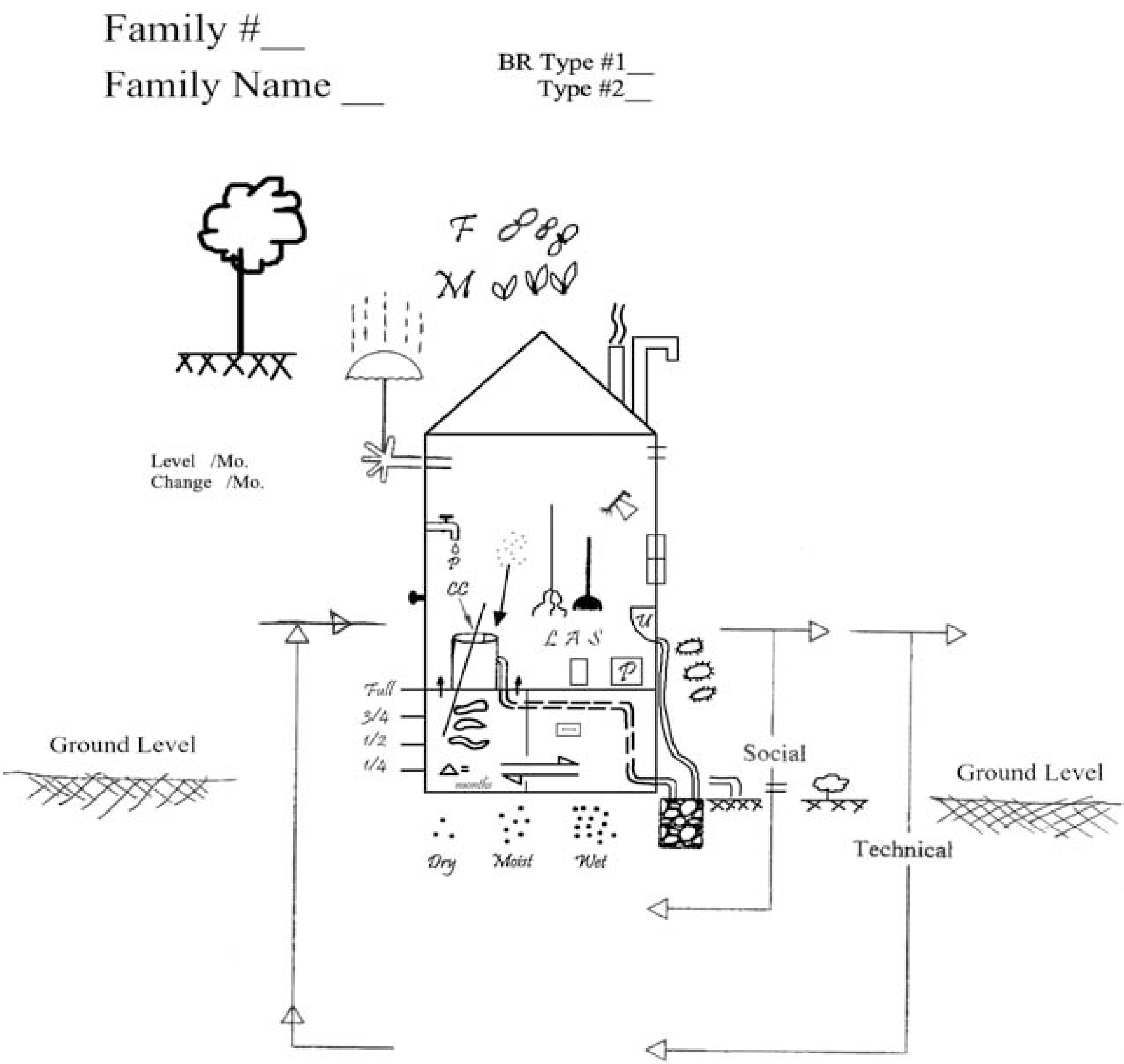

Figure 9.3 Desiccation Toilet User Feedback Loop (Diagram by Deanna Hambelton and Author)

Table 9.1
Moderately-Rapid Assessment of Most Pertinent Field Technical Parameters

#	Technical Parameter	Recommended Standard
1	Intermittent pH of waste in Active Vault	≥10 (@ 11, 100% NH_3 achieved)
2	pH of finished desiccated waste (compost)	8.75–9.25 or above if desired
3	Alkalinity (% Calcium Carbonate Equivilent)	Dilute waste with local soils; Thin application as agronomist recommends
4	Ambient Temperature	Warm, drier environments are best
5	Average Period of Repose of Each Vault	0.75–1.0 year (0.5 ok if managed well)
6	Average Treatment Period of Each Vault	Approx. 1.1 to 1.5 years (0.75 ok)
7	Approximate Size of Each Vault; Approximate Max. Volume of Each Vault	0.8 m high x 1.3 m deep x 0.85 m wide; Approx. 0.9 m^3 (approx. 32 ft^3)
8	Possible Volume Reduction	Volume reduction[1] by 50% possibly ok
9	Water Content in Vault Contents during Operation (% of Total Weight)	Perhaps 25–35% ok ≤ 20% prevents most microbial growth
10	Water Content Recommended in Finished Waste (% of Total Weight)	15–20% (5–10% observed); Squeezing waste sample with paper towel should not moisten towel
11	Fecal Coliform (MPN)	Use fecal coliform test kit(≤1000 MPN)
12	Minimum Solvita Maturity Index (if compost managed properly)	5.5 (Possibly lower)
13	Salts	If concerns, check w/local agronomist
14	Insects, Odors, Waste Visibility, &Handling[2]	As tolerable and desired by user
15	Additive Use	Generous amount after *every* use in order to *completely cover* the waste
16	Additive Type	Mix: Lots of Lime; some Ash & Soil

[1] Can be achieved by pre-filling vault halfway with soil (This accomplishes task of limiting detention time and shortening required follow-up period by outside technical support personnel). Floor dimensions can not be changed because of mobility reasons

[2] Insects, odors, waste aesthetics (or disagreeable nature) and waste handling all have a *social* component. The users' response, beliefs, and attitudes toward these physical/technical parameters are the *social factors* described and sought out in this report, and that need to be evaluated as part of the social side of moderately-rapid assessment.

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or teacher-student type approaches. The person is learning about health while they are learning how to build their new toilet.

Finally, it should be understood that the moderately-rapid assessment tool is not the filling out of a form and analyzing it, a one-day or one-week trip to the community, but instead, a moderately-long period of experiences with the community. Appendix M demonstrates the steps that would typically require a minimum of 1.5- to 2-year period. See Appendix N for an idealized project cycle according to WASH literature. Appendix DD shows the initiation and finalization of the support group's involvement. A non-enthusiastic, careful, good, slow beginning and disengagement is important. The initiation and engagement according to this illustration consists of well over half the support group's time and involvement. In concluding the introduction of the moderately-rapid assessment tools, the provision of information on information on well-know technological options and information on expressed technological options of interest is critical. Appendix O is a diagram that shows the most common sanitation options available. In the original source document, the current version of the desiccation toilet was not an illustrated option. It has been inserted in this diagram and others were eliminated. The community should be supported in any desires to explore and experiment with any of these options.

Lastly, appropriate forms of disseminating information should be used. See Figure 9.5 for an example of a brochure developed by local architect, cartoonist, and innovator Cesar Anorve. Figure 9.6 shows architectural styles, including one built but not replicated in Sonacala.

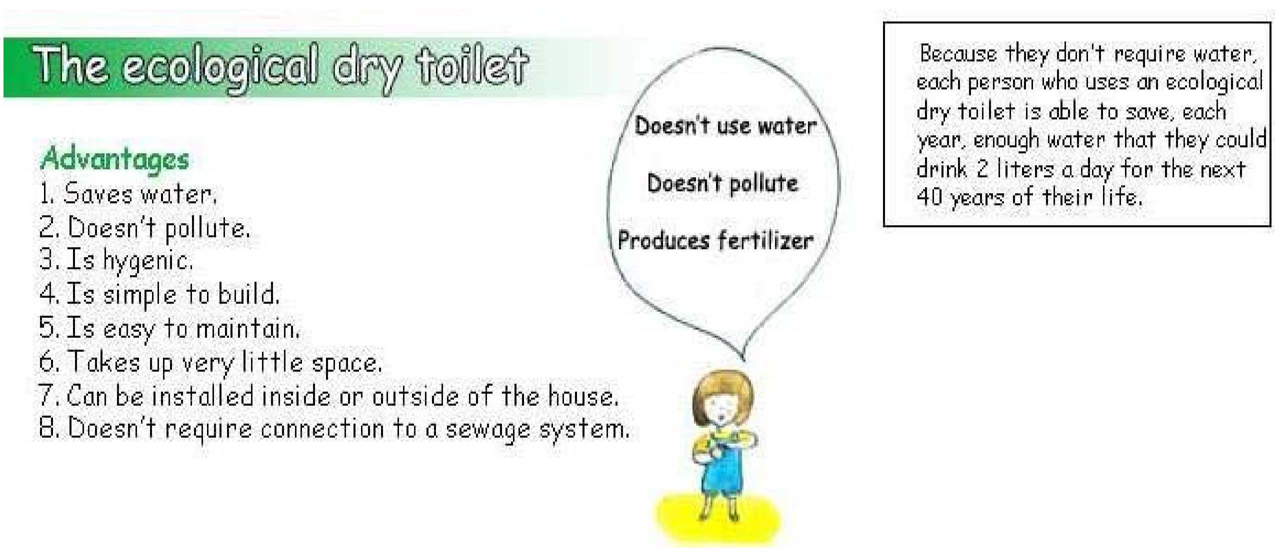

Figure 9.4 Cartoon-type Drawing of Advantages of Desiccation Toilet (Graphic by Cesar Anorve)

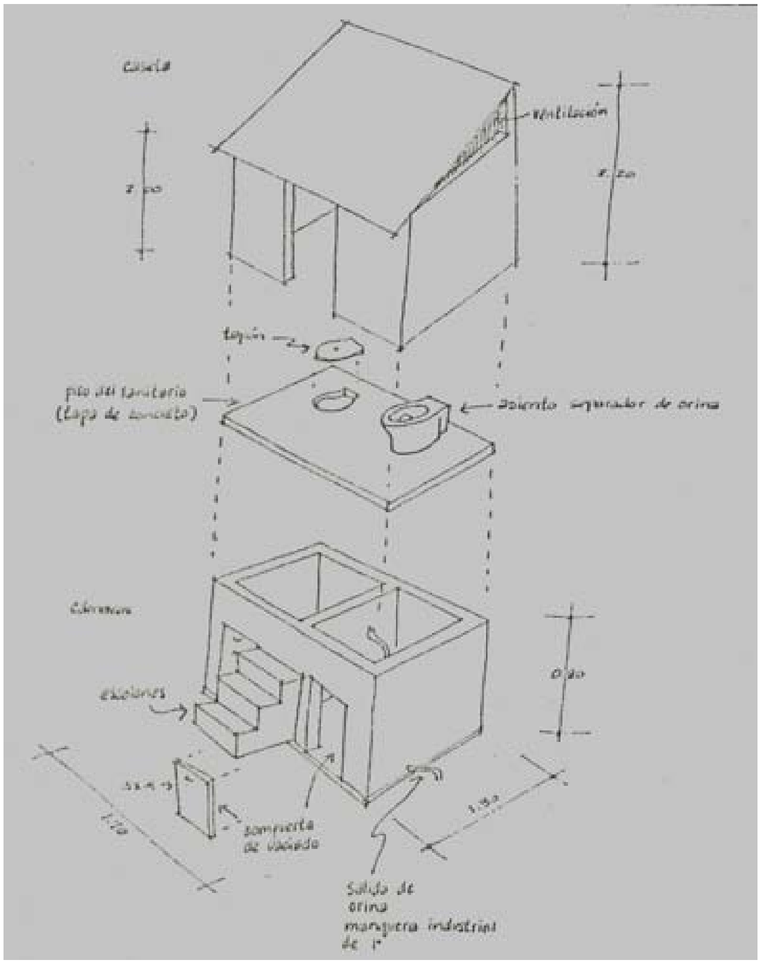

Figure 9.5 3-D View of Double-Vault Desiccation Toilet and Its Components (Drawing from publication by NOTI Diocese of Cuernavaca, Mexico, by Cesar Anorve)

Figure 9.6 Various Architectural Styles (Model on left built in Sonacala, but never replicated) (Photographs by Cesar Anorve)

CHAPTER 10. EXECUTIVE SUMMARY

The waste treatment process in the Mexican toilet investigated was determined to be a lime desiccation process where mean pH values of 8.2 of the finished waste appeared to be the key factor in the achievement of success in some of the toilets. Calcium oxide (quicklime), one of the three additives that cover the waste, was found to react with the water to form calcium hydroxide. In water, whose polar ends attract the ions of the calcium hydroxide, the two hydroxide molecules of the calcium hydroxide disassociate causing the increased pH environment—the first treatment mechanism. The higher pH values are the major contributor to disease prevention due to pathogen die-off. This pathogen die-off was confirmed by reduced values of the pathogen indicator—fecal coliform—with a mean value of 15.0 MPN/g with a standard deviation of 31.8, significantly less than the United States Environmental Protection Agency (USEPA) allowable limit of 1,000 MPN/g.

The conversion of the quicklime to the calcium hydroxide directly consumes and thus eliminates one molecule of water from the waste—the second mechanism of treatment. It was determined that reduction of water content was an important secondary mechanism in the treatment process. Mean water content value of 18.2 for the finished waste was below the 30 to 50 percent water content value required by microbes for ideal growth. The reaction of quicklime with the water held internally in the waste is a very exothermic reaction. The heat produced from this reaction further increased the drying out (desiccation) of the waste, along with externally-provided heat from the environment—the third and fourth treatment mechanisms. Elimination of ammonia by the reaction of ammonium with excess hydroxide molecules produced volatile ammonia which escaped to the atmosphere. Water is produced in this reaction, which is eliminated through excess quicklime. This was simply a physical-chemical process, which did not depend upon microbiological decomposition. This occurred in the waste whose pH values were mostly above 8.0 due to the quicklime added.

Removal of ammonium of the waste by its reaction with oxygen in the soil matrix prior to waste pile compaction was believed to occur on a small scale—the fifth treatment mechanism. This aerobic degradation, believed to be minor, was evidenced by the results from the Solvita® field test kits which indicated carbon dioxide in some of the samples, which would have been due to respiration of nitrifying bacteria. The first step of that nitrification process converts ammonium to nitrite and then a possible second step conversion to nitrate. When pH levels are low (below 8.5) this can and probably did occur in the waste, which was further evidenced by odors. When the waste pile is not mixed regularly and thoroughly, a non-homogeneous pile is formed. In the pile it is believed that two different types of pockets are formed. The first is with high pH (over 8.5), and perhaps pore space filled more with lime and/or water, rather than oxygen, where only lime desiccation can occur.

Solvita® test kits as a measure of compost maturity, stability, and phytotoxicity were helpful, however, with limits in their use with the higher pH samples (over 8.5). They were more practical than SOUR determination which can only be done in a sophisticated laboratory setting. Modification of the Solvita® field procedure by adjustment downward of the pH of the samples to below 8.5 will make the Solvita® test kits even more useful and accurate with the desiccation toilet waste analysis. A preliminary analysis of the published Solvita® general compost condition "process" diagram was performed in order to customize a conceptual revision of the current version of the graph, so that it can be designed more particularly for the desiccation toilet.

The reduction of ammonium reduced some of the oxygen demand. Oxygen demand was further reduced by the microbe's consumption of organic matter in the waste and conversion into the microbe's more stable body mass and its less-organic excrement. High reduction in organic matter was indicated by volatile solids' reduction to a mean of 15.8 percent ± sd 6.9. The entire mechanism for removal of the organic matter content could not be identified. Large consumption of organic matter by microbes did not appear to be possible after large quantities of lime were introduced due to pH levels which would have been too high. Large grub-like worms were also responsible, minimally, for consumption of organic matter, evidenced by visual observation of their body shell remains in the waste. In summary, increased pH, water consumption, water evaporation, ammonium volatilization, nitrification, and conversion of organic matter into biomass were all found to be part of the waste treatment process.

Remaining oxygen demand was determined to be substantial and a moderately inherent harmful impact to local water supplies (receiving streams and groundwater), if not disposed of properly, particularly in densely populated areas. Approximately half of the waste samples were determined to be in an inhibited state due to excess nitrogen resulting from the high pH environment, with minimal microbial decomposition possible due to an unfavorable environment of high pH, low moisture, and toxic levels of ammonia. That latent oxygen demand was evidenced by SOUR values (as expressed in volatile solids) significantly higher than typical values for compost. Analysis of SOUR on a per unit total solids basis indicated otherwise, that SOUR concentrations in the waste were close to or below the EPA allowable limits, which is expressed in total solids. Although the volatile solids expression was more traditional, the total solids analysis appeared to explain the data more logically for the samples collected.

In the inhibited waste, the "locked up" organic matter content, ammonium and alkalinity, all have the potential to be released upon re-moisturizing of the waste (and possible reduction of the pH). The re-moisturizing of the waste could occur if and when the waste is *dumped* in a batch in the environment, as opposed to adequate spreading or tilling, as should be done. The re-moisturizing would occur when and if rainwater and/or stormwater contacts the waste. It was determined that through mixing of the waste in the desiccation toilet vault, mixing of the finished waste upon removal after the repose period (6 to 12 months), and a thin land application of the waste could possibly prevent these adverse impacts. Another technique recommended to dilute the waste is to pre-fill the vaults halfway with soil or sand and then thoroughly mix the vault contents after removal and prior to disposal or use. Mixing was believed not to be adequate. The continued use of high amounts of lime while allowing the highly alkaline non-uniform treatment of the partially-mixed waste appeared to be the only currently successful method to treat the waste in developing areas where operation and maintenance practices are inferior. In analysis of some samples, alkalinity was determined to be the limiting factor for disposal or application of the waste to local alkaline soils, not pH. Application rates as thin as 1/10” were calculated. From this perspective the waste would have to be spread thin for reasons of alkalinity and for oxygen demand. The only other choice was to apply it to high-feeder crops such as corn or sorghum—tall plants—whose food product is protected from potential remaining pathogens in the compost waste. An alternative to use of high quantities of lime is the use of higher quantities of wood ash, which also contains a 25 percent equivalency of calcium carbonate, along with soil. However, caution should be exercised in encouraging that practice, which could result in users cutting timber to create ash, a harmful practice in some areas.

Micronutrients were not a concern, nor were heavy metals or nitrates. In Sonacala, the finished treated desiccated waste had some, but little, agricultural value in respect to satisfying soil macronutrient needs for phosphorus, potassium, and nitrogen, thus reducing the applicability of the term “compost” as a descriptor of this waste. However, in the Guatemala project, it was reported that there were increases in crop production where the waste was applied as a compost. As the logical counterpart, the process did accomplish its role of partial elimination of nitrogen—reducing the oxygen demand and not requiring water for its functioning.

Various modifications to the traditional design were analyzed. Design improvements were made to improve vault access to make waste handling and mixing more manageable. An additional trap door or *brick window* on each side of the toilet could make periodic mixing more thorough. The addition to the typical design of a diagonal downward extension of the back of the vault with a large door could also make regular mixing easier and less disagreeable. Installation of a steel *hoe* through the wall or floor would assist with leveling.

Of utmost importance were changes to the toilet basin to improve its aesthetic value. Improvements to toilet basin aesthetics include a re-design of the back wall of the basin to slant away from the basin opening which would result in less soiling of the back of the basin. It is this soiling that is partially responsible for decreased aesthetics and increased need to clean the basin wall. Alternatively, different types of liners could be placed or built into the inside of the toilet basin. A removable washable plastic liner is the first option. A thin coat of weak cement mortar that would deteriorate over time and flake off into the vault would be another option. Last of all is a type of very thin cardboard liner or thick paper liner that, after becoming unacceptably soiled, could be cut off and allowed to drop into the vault. The importance of pursuing a viable option to a more aesthetic toilet basin is believed to be important in increasing social acceptance.

Changes to operational processes to reduce unneeded counterproductive long retention (treatment) times were developed. This reduction was important so that the exterior support group would more likely still be working with the community and would be present for the critical-waste handling period. The first method to reduce retention times is to simply pre-fill the vaults half way. Secondly, the development group would simply put on their calendar to re-visit the community a minimum of once every 3 to 6 months for approximately two years. This would get the community through a lot of the vault changeovers and help overcome their fears and concerns regarding the process. All of these design and operational changes were considered critical in increasing acceptance and success of the toilet.

CHAPTER 11. RESULTS

The results on the treatment processes and associated treatment standards were:

1) The waste treatment process is definitely a lime desiccation process; there were other processes found, but not extremely significant ones.
2) The raising of the pH with quicklime is more important than lowering the water content.
3) The vector attraction reduction goal (i.e., disease prevention) was met with an average MPN/g of less than 1,000 for the investigated and the two other communities.
4) Curing, as indicated by the mean field Solvita® maturity index value of 4.0 ± sd 2.3, was below the project minimum standard of 6.5 in all but one of the six samples and was representative of inadequate composting processes; however, since fecal coliform counts were within guidelines, these lower values were acceptable in reference to a view of the toilet as a non-compost treatment device. The maturity index standard was adjusted to 5.5, with the condition that the finished waste be managed well. This standard, however, could be waived if waste is applied to high-feeder tall plants. The waste application must be managed well by ensuring careful application to ensure not to burn the plants, adequate soil dilution, and keeping surface water out of the applied area.
5) Remaining oxygen demand was high and EPA vector attraction reduction requirement was not met, as indicated by volatile solids-based SOUR limits, promulgated by typical values reported by the Callegari Center and SOUR equivalencies developed by the Woods Ends Research Laboratory. On the other hand, SOUR as reported on a total solids basis was substantially in compliance with the EPA requirement. It was considered that the total solids basis for volatile solids more accurately described the waste, since the inorganic fraction was also important in the description of the desiccated waste, as a biosolid, as opposed to compost classification which is only concerned with the organic fraction.
6) Solvita® test kits were helpful in waste characterization, particularly in the unstable nature of many of the samples. Field adjustment of pH to below 8.5 was determined necessary to ensure accurate readings. Field fecal coliform kits would be a complementary field assessment technique also, especially when other results are not clear.
7) Micronutrients were all lower than required minimum amounts for agricultural needs, except sulfur which had a mean value of 3,684 ppm compared to the limit of 1,300 ppm. Those concentrations are not of concern.
8) Lead, arsenic, nor any other heavy metal or nitrites were of concern.
9) The finished treated desiccated waste had some, but little, agricultural value in respect to satisfying soil macronutrient needs for phosphorus, potassium, and nitrogen; however, the process did accomplish its role of reducing the nitrogen content and did not require water for its functioning.
10) In some analysis, alkalinity was the limiting factor, not pH, for disposal and/or application of the waste to local slightly alkaline soils.

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Results of the analysis of related adverse conditions were:

1) Odors and insects (i.e., flies) were the most frequently reported problems, especially with the fiberglass toilets. There was one report of great concern that there was a massive fly infestation that caused many to reject the toilets where the infestations occurred and decreased overall prestige and ruputation of the toilet.
2) The desiccation toilet was perceived by some to be non-hygienic.
3) When not properly operated and maintained, the desiccation toilet does have significant odor, insects, aesthetic, and waste-handling problems that did result in toilets that failed and were rejected, or at a minimum, acceptance was reduced. Where proper O&M occurred, it appears these were not significant problems.
4) The social acceptance rate by individual households of the toilets appeared low. There were commentaries received that large numbers of desiccation toilets were rejected. Those households were not visited (because project goal was to evaluate actual toilets still in use) nor was their technical success or failure known.

Results on toilet types and some design recommendations were:

1) The vaults for the brick toilet were drastically overdesigned, detention times were unnecessarily long, waste was over-aged, and treatment efficiency higher than required.
2) Brick and block toilet models appeared to be more preferred.
3) There were many negative reports on the fiberglass toilet, particularly in reference to the high temperature inside the shelter and strong odors. The fiberglass model was the least preferred by the investigation team members. It was rejected as a viable model by all team members except one.
4) The less airtight design of fiberglass toilets provided more ventilation of gases and vapor.
5) The fiberglass model has some *intermittent* use potential to projects. Its portability and removable vaults may be able to play a role in experimentation and training with new users. The preferred and best location of the toilet could be identified by moving the portable facility around the site as desired and each location experimented with until the family finds a location that suits their need for privacy, proximity, distance, and shade. Technical staff can assist with removal and diposal or re-use of the waste at the end of the first cycle of the removable bin. Staff member’s demonstration of the removal technique and his comfort level can provide reassurance, confidence, and acceptance to the user.
6) The concept of a removable waste bin should be experimented with for the brick and block models. A larger removable bin could be inserted in the enclosed vaults and used for experimental purposes or on a long-term basis.

Most significant operation and maintenance results were:

1) Twenty cubic feet of sand or soil (“general fill”) be required to be obtained for later use.
2) Fourteen cubic feet of the above general fill (sand or soil) be required to be placed in the first vault prior to its completion (filled about halfway).
3) Large quantities (i.e., 3 cubic feet) of soil and/or ash (“general additive”) should be required to be prepared prior to initiation of construction and program support and stored for future use as the toilet additive.
4) “General additive” must be placed in the vault intermittently when odor, insect, or visibility problems arise.

5) When vaults are half to three-quarters full, six cubic feet of the above “general fill” (sand or soil) should be placed in vault to seal and top it off.
6) After every use of toilet, it is required that an addition of approximately 1 to 3 cups of “high-pH additive” (consider equal parts of lime, soil, and ash) be applied. The pH of the mix should be a minimum of a pH of 10.
7) A requirement that one cubic foot of the “high pH” mix be prepared prior to the end of construction.
8) Prohibition of introduction of urine, bleach, water, or any other liquid into the vault.
9) Pre-caution regarding care to not allow bleach and quicklime to come in contact (a deadly gas is reported to be produced). Use of bleach to clean floor of shelter is not advised.
10) Technical assistance and follow-up required at a minimum at switching to second vault (3 to 6 months) and emptying of first vault (6 to 12 months).
11) Feedback from a qualified team and a method to provide that feedback to users is needed to assist focused on converting user experiences and concerns to valuable knowledge and know-how.

Anthropological methods are detailed in Appendix P and are described and summarized in below. The assessment termed “*moderately*-rapid assessment” conducted with a small, rural Mexican community using the field investigative technique of triangulation, combined with a tool developed by James Bebee (1995) called “rapid assessment” was successfully employed. Triangulation used as an anthropological ethnographic approach, was a constructive tool that did involve and gain the following: 1) participant observation, that is, the investigator being in the community for a long period to observe the communities’ behavior, participate in their daily activities, and view the world through their viewpoint, 2) review of what others have done on the subject of the investigation, and 3) informant consultation of local experts. In Bebee’s rapid assessment approach, the required tasks were to a) have a multi-disciplinary team, b) have more than one investigator, and c) make an immediate assessment. They were all accomplished to a reasonable degree. The triangulation approach was conducted over a 20-year period while the rapid assessment was done in approximately two weeks. Combining the strengths and weaknesses of both methods it was determined that only a *moderately-slow* assessment at the best could be done, in this case a time frame of 20 years. Considering that the investigators were not in the community full-time, the 14 years in the community was not enough[3]. More practically, in the case of desiccation toilets, a moderate period will be considered a minimum of 13 to 25 months—1 month for planning, 5 months for technology review and experimentation, 1 month for construction and 6 to 18 months to observe the operation and maintenance of the toilet and to analyze the waste at the end of the second vault’s closure. This would be after 3-9 months of treatment in the second vault, and 3-9 months of previous treatment in the first vault[4]. Assisting the users through this critical waste handling, use, and/or disposal task was critical and

[3] Some anthropologist spend their entire careers living in one community and is not considered long enough.

[4] A rapid assessment period is possible of 1 week for planning, 2 weeks for technology review, 1 week for construction, and 10 months for operation and maintenance observation including vault switching and emptying.

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helpful for cases as indicated by successes at those families. Observations were made over the 14-year period of peculiar activities that were not possible to see in the two-week period of the rapid assessment.

Literature showed that a developmental project is typically a seven-year cycle, which in this case, the non-profit intervening organization fell short from the standpoint of close-enough contact with the community. The decreased intensity of follow-up from this non-profit group in years 5 through 7 was believed to be a factor in the eventual rejection of approximately 80 percent of the facilities. During the 5- to 10-year period when the non-profit group had already started to withdraw, there were new competing technologies (the block and fiberglass versions of the same concept), promotional propaganda, and philosophies. Also these played a role and were influential. The governmental and also the private, for profit business, and the pre-existing influence of the existing *modern* sanitation conventional toilets entered the picture. All three started to challenge the compost toilet concept, decreasing its prestige and acceptance. It also perhaps even caused confusion due to this misinformation being spread around the village. Governmental agencies' strategies are more top-down and do not sometimes have the same commitment and beliefs of grass-root philosophies, environmentalism, and innovative technologies. The business and the sponsoring municipality were probably critical of the other models and perhaps only interested in reaping profits and gaining popularity and votes. This type of political aspect was seen in a community project in which the non-profit group participated just prior to this project.

Even with all these problematic influences, not all was lost—perhaps something was gained in the long run. First of all, the competing technologies and organizations brought to the surface disadvantages and weaknesses of the originally-introduced brick model and that project. This new information and experience enabled innovative changes to be made to the design and operation and maintenance approaches to all three technologies. Secondly, the dynamics of competition improved the technology, the program approach, and the skills of the investigators. Also, conceptually for the community, the new sanitation question became not only if the originally introduced brick toilet version was a successful and acceptable technology, but which model was better. A comparative analysis began to be made by the users. Literature further demonstrated that villagers do benefit-cost analysis in weighing the advantages and disadvantages of participating in new community projects. In this case, a change of their sanitation habit was the point of analysis made. Their new question was whether to change, from either the status quo practice of indiscriminate defecation in the field or from the increasingly-more popular waterborne toilets, to now evaluating which of the three compost toilet types to switch to and adopt. The thought probably was "I don't like the fiberglass model but the block model is OK and more aesthetically pleasing and sound than those brick toilets with those worn out brick toilet shelters" (which *were* starting to deteriorate from weathering).

It was seen over the 14-year period in the village that the community became more populated, water shortages continued, and incomes continued to be limited. If these trends continue, it is believed that the acceptance of the desiccation compost toilet will increase again. As community members continue to struggle economically, and financially possibly worsen, it is further believed that the inexpensive compost toilet will be seen as the only current technology that is practical, affordable, and buildable in the rocky terrain where the water-borne system has problems in its construction and use. This is why the local architect only promotes the desiccation toilet.

Scientific versus indigenous health beliefs were investigated by asking users about their possible use of natural medicines. In a few cases, users indicated that they had non-scientific beliefs concerning health and sanitation. Various individuals, though, stated that they use natural medicine, which was considered an overt sign of sub-conscious health and disease theory beliefs based on the Greek humoral system, adopted in Latin America hundreds of years ago.

Other issues confirmed were social beliefs concerning sanitation practices, waste handling, and the process of change with the individual and community. Changing community demographics were shown to influence and increase the rejection of the newly-introduced sanitation technology. Social factors investigated were more, ones specific to the individual, not the community. Influential social factors were found to be "grounded in science and the physical world" with lesser ones based on philosophical constructs or lofty thinking. Theorizing was considered *boring* ("rollo") to the practical Mexican people and such talk and discussion to be concepts *in the sky* ("en las nubes"). It was seen that the Mexican user's perspective, beliefs, and actions were based on their physical reality and their struggle to improve their lives, in particular in this case for their need for basic services to meet their basic human needs for sanitation and health. Practical desires such as comfort, convenience, cleanliness, and distance (proximity and separation) were factors found to be more motivational than a desire to improve health. The practical problems with the toilet such as odors, insects, aesthetics, waste handling, poor use based on inadequate knowledge, training, and experience, were identified as key factors in acceptance or rejection, and in the success or failure of the toilet.

Although an attempt to link the sanitation activity to water supply and water quality improvements was made, but not extensively implemented, it was shown that the linkage is critical for sanitation technology and program acceptance and sustainability. Although organizational and program theories and factors required for successful developmental project implementation were not the specific theme of the investigation, they were reviewed on a broader regional and international basis and a long list of critical factors was provided.

Uncertainty in social factors, motivations, and willingness of individuals to participate, created uncertainty in the program methods and approaches. This resulted in an approach that was based on use of pilot projects to give people real experiences, combined with outside technical support, with feedback from users incorporated into the project in a behavioral-change format approach to introduce new technology. It was set forth that investigators have to feel comfortable with uncertainty and not hasten to make judgments based on conceptual theories, but instead to stay grounded in the practical realities of the sanitation activity and the people's stated desires, but confirmed with their behaviors.

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A simple graphical form (no text) was developed for use by community technical support workers to pictorially represent field assessments of the status of the technologies' acceptance and success as its use proceeds. Simple field technical approaches and sampling kits were used and modified to be able to make technical assessment right in the field within two day's time. This approach will enable technicians to provide feedback immediately to users, which is key to the sustainability of this technology. Some key results were:

1) The social factors identified *were* influential in the acceptance and rejection of the technology (see Table P.2).
2) Only faint indigenous health values, related to natural medicine, were potentially perceived in the village.
3) Although the germ theory of science is believed to predominate analytical perceptions of the waste, illness, and healing; villagers do have different logic, thus making ineffective some aspects of health-based initiatives.
4) Villagers use benefit/cost analysis to assess value and make their decisions.
5) Social acceptance and technology design and implementation all change over time.
6) There were various social factors that *could not* be identified, thus requiring the need for a system of continuous feedback employed for technology and project modification, and pilot projects to allow the social factors to play out — to let time tell its story.
7) Continued conjecture of influential social factors and social indicators of success should not be made nor should invention of more pink elephants.
8) Uncertainty is acceptable.
9) Local architect and innovator is more optimistic about the desiccation toilet than is represented in some parts of this report (see Figure 11.1 for one of his depictions).

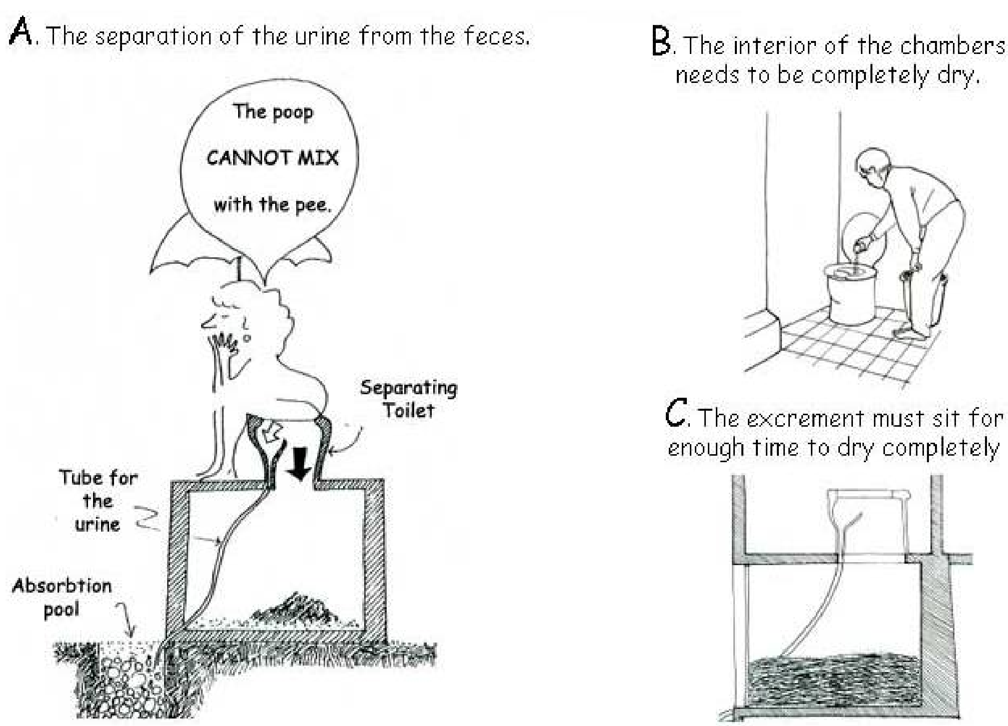

Figure 11.1 Educational Drawing Depicting Key Toilet Concepts (Drawing by Cesar Anorve)

CHAPTER 12. CONCLUSIONS

The engineering conclusions were:

1) Overall project had limited success.
2) There were some tremendous successes at individual households.
3) Adequate new standards were developed for the following with high levels of certainty:
    a. Design features of the toilet vaults and shelter
    b. Improved design of toilet basin and appurtenances
    c. Technical standards for the finished waste (“discharge standards”)
    d. Improved operation and maintenance procedures and standards.
4) Acceptance and success can be increased with implementation of new standards outlined above. Acceptance may only be achieved with significant increased valuation by the community of this technology’s benefits versus its cost. Successful project implementation methods will be needed also.
5) Some elements in the definition of benefits, success and acceptability of the toilet by community members were the absence of offensive odors or insects, the actual household’s degree of need for non-waterborne toilets, and convience, privacy, proximity, and comfort reasons. The absence of social stigma and criticism from community or from neighbors was considered an influential element in acceptability.
6) The desiccation toilet technology was viewed by some, if not most, as an experimental, unproven, and inadequate technology. This perspective was established without the individual having the benefit of any experience with the toilet.

The anthropological conclusions were:

1) Overall project had limited acceptance.
2) Total coverage of community was low, estimated between 5-20 percent, perhaps higher, considering that replacement of one toilet type with another would result in *no net loss*.
3) There was high levels of satisfaction at some households with high levels of treatment obtained.
4) There were some toilets that had long-term acceptance, though even in most of those cases the technology was viewed as an intermediate step. Regardless, many families continued to use the technology, some because they had no other feasible options. In a sense, they were “stuck” with the technology.
5) Design improvements incorporated user concerns, most importantly the toilet basin, to improve its aesthetics. One local innovator has professionally developed all the features of the toilet, manufactured all the necessary components and has provides them at very reasonable prices, often under-cost for social reasons (see Figure 12.1).
6) Acceptance and success can be increased mostly by improved operation and maintenance, and largely through use of adequate, sufficient additive, design, inclusion of an additive reservoir, an automatic additive delivery system, an improved and easily maintained toilet basin, and easier, more-agreeable vault access and waste removal and disposal and re-use techniques.

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7) Acceptance may be achieved with significantly increased valuation by the community of this technology's benefits versus its cost. Successful project implementation methods will be needed also.
8) The absence of social stigma and community criticism from neighbors was considered an influence on acceptability by some households, and its presence influencing decreased acceptability and possibly rejection.
9) It appeared that the community's perception of their sanitation needs changed. Initially, the most predominant question was if the brick model of the toilet worked. With the introduction of the other model types, the new question was which of the three model types was best. The community began to do comparative analysis and further develop their concept of sanitation and hygiene. Attitudes, beliefs, and practices evolved.
10) Waterborne sanitation options continue to be desired as the preferred option, where and when water was available.
11) This technology proved to be a low cost, low-maintenance, only moderately-appropriate technology, especially the brick models (U.S. $100 to $250), the block models ($200 to $300), and much less the fiberglass models (estimated U.S. $800; see updated construction budget attached for brick model). The desiccation toilet was more appropriate where households understood its values and requirements and accepted the non-waterborne nature of the toilet.

The bottom line is that the central Mexico desiccation toilet in Sonacala was a technology with only a small current degree of success and acceptance, when operated properly. As with any technology, poor operation and maintenance can cause this toilet to malfunction and become a point source of contamination. Improved design and operation and maintenance standards were developed and should increase technology success and acceptability. The new prototype of this desiccation toilet is being termed the "improved alkaline desiccation compost toilet" (IADCT) and as such is not a composting process, but instead an efficient controllable desiccation treatment process.

Figure 12.1 Parts and Appurtenances for Desiccation Toilet Manufactured in Cuernavaca, Mexico (Figure from Catalogue of the Center for Technology Innovation)

CHAPTER 13. UNIQUE AND NOVEL CONTRIBUTIONS

This multi-faceted work consisting of the two disciplines—engineering and anthropology—produced unique and novel contributions in the following areas:

1) Conducted *comprehensive* evaluation of the desiccation toilet. Clearly defined the alkaline desiccation process as the overriding treatment mechanism which must be given priority. Determined that composting is not a principal process, which typically has to be sacrificed as a treatment process for the sake of the maximizing the desiccation process.
2) Produced the technical standards for the initial toilet construction and the criteria of technical evaluation for its ongoing assessment. Part of this process was the establishment of the technical side of the assessment tool in Table 9.1. These technical standards and evaluation criteria gives the *experienced* technician the ability to go into a community and make an as-rapid-as-possible assessment to judge whether a technology has been successful. These standards and criteria have not been available. On-site evaluation is critical in the life of this technology, which is still in its infancy having only been invented in 1959 and introduced later to Latin America. It is still evolving and critical judgments are being made regarding the status of this technology. Adequate assessment is needed to provide feedback to users to improve its operation and success, and to provide information to governmental and private groups who have a need to evaluate the status of this technology for the purpose of sponsoring desiccation toilet programs or providing assistance to toilet facilities already in existence.
3) Modified the Solvita® compost kit use procedure to adopt it for successful use with desiccation toilets. Validation and use of the Solvita® test kits for the quick and accurate evaluation of the toilets can be critical in user education and confidence. The provision of this information could be critical to the governmental and private sector groups sponsoring or considering sponsoring desiccation toilet programs.
4) Discovered the ASH/volatile solids ratio introduced as a technical parameter with a sociological component which has the potential to evaluate the technical success of a toilet and also provide a parameter with meaning to the geographic area and users in Mexico who currently own and operate these desiccation toilets.
5) Identified over 100 social factors potentially applicable in development projects in general, and ones more probable in desiccation toilet programs. Clarified the limited ability for planners to account for these factors in program design and preparation, created the MRA (moderately-rapid assessment) tool to attempt to evaluate these social factors, and clarified the need for pilot projects to let time tell the story as to how these social factors will impact and influence the technology's acceptance or rejection.
6) Identified social indicators of acceptance which are the *flags* that indicate *cues* from users and the community as to their attitudes and beliefs and hints possibly at their actual behavior which is the true indicator of their beliefs, attitudes, and commitments. Incorporated the social factors into the assessment tool in Table 9.1.
7) Developed a combined evaluation tool termed "moderately-rapid assessment," with realistic time frames required for its use and established technical-social linkage.

CHAPTER 14. RECOMMENDATIONS FOR FURTHER STUDY

The following items deserve further research.

1) Future research with intervention in the process directly before the vault is full.
2) Mechanism in place so that developmental staff know when to return to the community.
3) Intervention with users when problems, especially prior to potential failure.
4) Investigation directed at abandoned toilets, using short curbside interviews.
5) Longer interview for families willing to participate. A fixed fee, up front compensation, could be offered.
6) Improved pH and moisture data monitoring techniques.
7) A further analysis of the Solvita® Process diagram. The different considered pathways and process diagrams shown and analyzed should be verified and analyzed to determine the characterization of the treatment process and recommended additive use, pH levels and operational and maintenance activities that can maximize the treatment per the newly-configured decomposition diagram.

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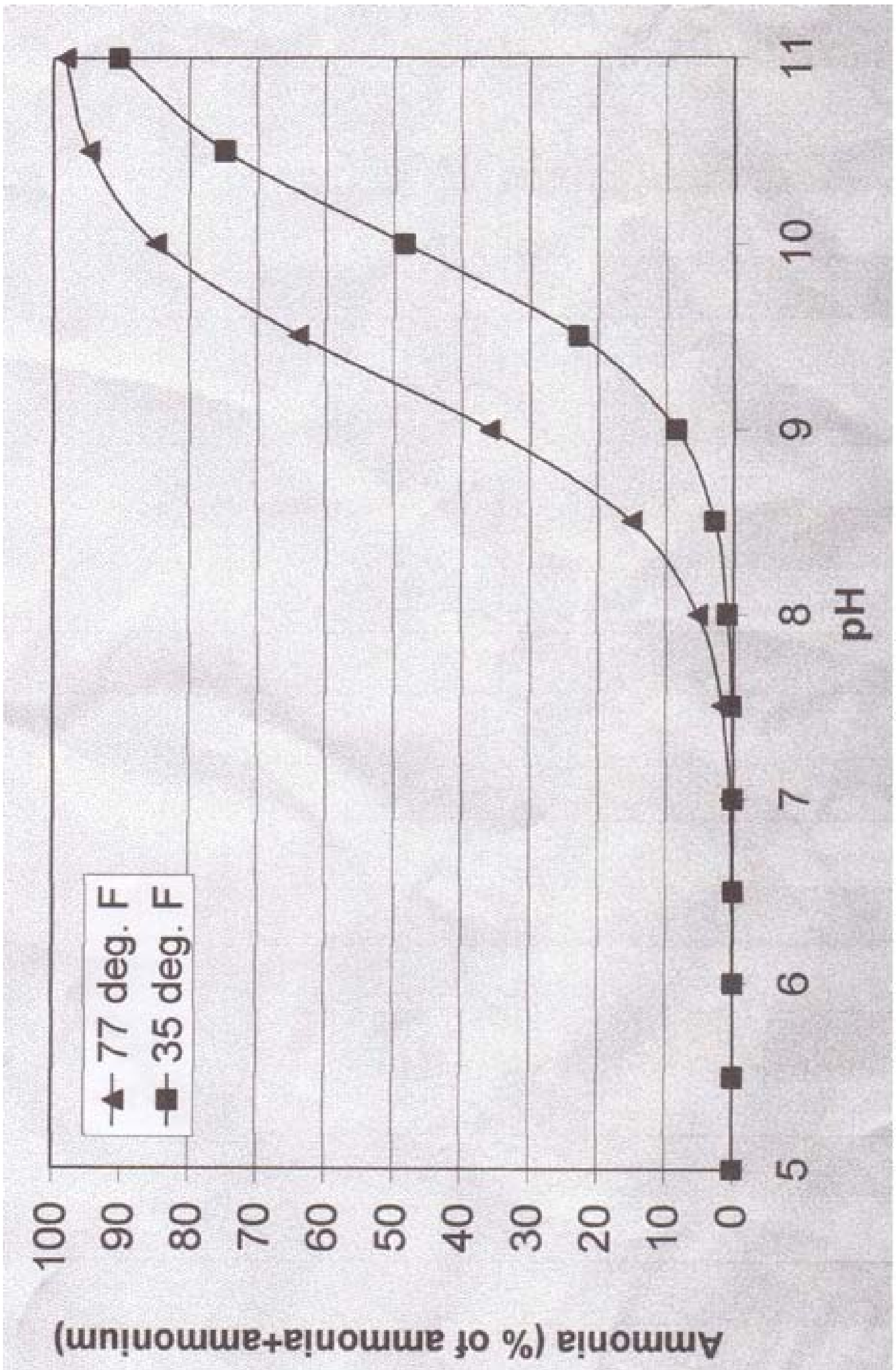
APPENDIX A

PERCENTAGE VOLITILIZATION OF AMMONIUM VERSUS pH



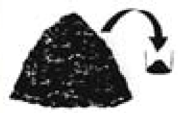
* Graphics by University of Idaho

APPENDIX B

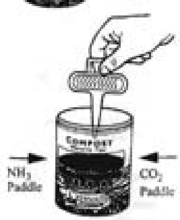
WASTE SAMPLE PREPARATION AND SOLVITA® TEST

INSTRUCTIONS

Detailed sampling instructions are available at: www.woodsend.org



lbs/ yd³	kg/m³	g / jar
600	300	30
800	400	40
1,000	500	50
1,200	600	60



SAMPLE PREPARATION

1. OBTAIN SAMPLE: Make a composite sample by mixing several sub-samples representing the compost to be tested.

2. SCREENING: Remove or screen-out wood chips and large fragments before testing. A $^3/_8$" (10mm) sieve is customary.

3. CHECK MOISTURE: Compost should only be tested when at ideal moisture for proper composting. Compost that is too dry may have suppressed respiration and therefore may give a false positive for maturity. Try the squeeze test[1].

4. LOAD COMPOST: Fill the Solvita jar to the indicated fill line. Samples are meant to be tested at field volume density. When compost is disturbed the porosity may increase. To get the proper density it is useful to sharply tap the jar while observing the fill line. Optionally, the proper weight in grams per jar of suitably moistened compost corresponding to actual field density is found in the table at the left.

5. EQUILIBRATION STEP: Let the sample "air-out" in the jar for one-hour prior to starting the test. If the sample was taken directly from a very hot or frozen pile, or if it needed remoistening after being too dry, then let it sit in the test jar overnight with the lid open before starting the test. This improves the reliability of the respiration reading.

6. START TEST: The Solvita test is two tests in one, carried out in the same 4-hour period. Open the individual pouches marked "Compost CO_2" or "Ammonia" and carefully remove each paddle. The gel in the paddles is color-coded: the carbon-dioxide paddle is purple and the ammonia paddle is yellow. *Do not touch the special gel surface, and don't allow compost to touch it.* Once the gelpack is opened, the test should be started within 30-minutes as it will start absorbing gases from the atmosphere.

7. INSERT PADDLES: Both paddles are pushed into the sample in the jar according to the cue marks on the jar, and may be observed through the clear back panel. The edges of the paddles can be touching in the middle at about right angles. Push the paddle tips all the way into the compost to the bottom of the jar. Do not jostle or tip the jar which may coat the gel paddles!

1. **Squeeze test:** make a fistful of compost. Squeeze very hard. Moisture should appear between fingers but not drip out if compost is at the proper moisture content.

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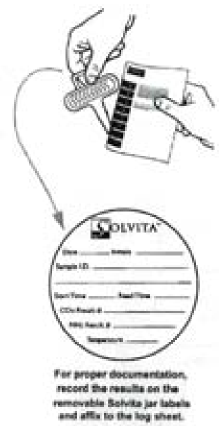

RUNNING THE SOLVITA TEST

8. SCREW THE LID TIGHT, and keep the jar at room temperature (68—77°F or 20—25°C) *out of direct sunlight* for 4 hours.

9. READ THE GEL COLOR. At the correct time (4 hours) after the jar has been sealed, remove the paddles one at a time from the jar and hold next to the correct color chart. Compare the gel color to the numbered color scales, finding the closest match (half shades of color may also be read). Read within 5-minutes after removing from the jar. Color matching is best under fluorescent room light. Mark the results on the lid label on the jar.

10. FILL IN THE VALIDATION FORM: Provided in the kit is a removable lid label to aid in the documentation of the results from Solvita testing. A pre-punched monitoring sheet is provided along with the test kit. The Solvita lid label may be peeled off the jar after the test and affixed to the monitoring sheet and stored in a binder to document the test.

11. FIND THE MATURITY INDEX: Using both paddle numbers from the color chart, read the table below to find the intersection of the CO_2 and Ammonia values. See also Tables 2-3-4 to separately estimate ammonia content and ammonia hazards.

SOLVITA® BY WOODS END® RESEARCH
P.O. Box 297 • Mt. Vernon, ME 04352

COMPOST MATURITY
AMMONIA TEST
(paddle "A")
- please see instructions for use -

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Source: Woods End Laboratory

APPENDIX C

HEAVY METALS AND OTHER PARAMETERS

Element Name	Symbol	Limit1 (mg/kg)	Limit2 (mg/kg)	Other Limit (mg/kg)	Actual Concentration (mg/kg)	Standard Deviation (mg/kg)
Aluminum	AL		-		12,407	7283
Boron	B	-	-		30	39
Calcium	Ca	-	-	54,000	146,383	69,176
Copper	Cu	4300	1500		46.6	14.8
Iron	Fe	-	-		8036	3375
Magnesium	Mg	-	-	-	15,762	4749
Manganese	Mn	-	-	-	206	61.6
Molybdenum	Mo	75	-		-0.3	0.0
Phosphorus	P	-	-	32,000	11,678	3323
Potassium	K	-	-	17,000	18,070	5192
Sodium	Na	-	-	1300	3781	974
Zinc	Zn	-	-	7500	199	32
Arsenic	An	75	41	-	-	-
Cadmium	Cd	300	39	-	-	-
Lead	Pb	840	300	-	-	-
Mercury	Hg	57	17	-	-	-
Nickel	Ni	420	420	-	-	-
Selinium	Se	100	100	-	-	-

`

APPENDIX D

EXAMPLE CALCULATION OF LIMITATION ON APPLICATION RATE TO SOIL BASED ON ALKALINITY (1999 SAMPLES)

Below is a series of tables produced as a result of an analysis of a compost sample (MSS5), soil sample (MDS4), and lime sample (MLS5) for a sample withdrawn from a compost toilet in Sonacala in 1999. The results indicate that the alkalinity was the limiting factor, which controlled the application rate. The waste would have to be applied at 1/10" to prevent harm to existing soils. This application rate could continue for 20 years without harm to the soils. The calculations also demonstrated that while the waste had very little compost value, it was very efficient at removing nitrogen. Various parameters are presented in Tables D.1 through D.3 (Bates, 1999).

Table D.1
Beneficial Parameters

PARAMETER	PARAMETER TYPE	RATE REQUIRED	ANALYTICAL PROCEDURE
Available Nitrogen	Macro-Nutrient	145 lb/acre	TKN (Organic N + NH_3 + NH_4^+) plus Nitrites plus Nitrates (0) (Malone Lab)
Phosphorus	Macro-Nutrient	60 lb/acre	Agronomy Dept.
Potassium	Macro-Nutrient	60 lb/acre	Agronomy Dept.
Magnesium	Secondary Nutrient	Minimal	Agronomy Dept.
Calcium	Secondary Nutrient	Minimal	Agronomy Dept.
Sulfur	Secondary Nutrient	Minimal	Agronomy Dept.
Organic Matter	Other	6%	Agronomy Dept.

Table D.2
Detrimental Parameters
(Micro-Nutrients)

PARAMETER	ELEMENT TYPE	ANALYTICAL PROCEDURE	LIMIT (ppm)
Copper (Cu)	Micro-Nutrient (Heavy Metals)	Agronomy Dept.	4300
Iron (Fe)	”	”	-
Manganese (Mn)	”	”	-
Zinc (Zn)	”	”	7500
Arsenic (As)	”	”	75
Cadmium (Cd)	”	”	85
Nickel (Ni)	”	”	420
Lead (Pb)	”	”	840
Boron (B)	”	”	-
Aluminum (Al)	”	”	-
MPN	Bacterialogical	Not performed since microbial contamination not within report scope	Fecal Coliform Density <1000 MPN/g TS or Salmonella specific density <3 MPH/4g TS

Table D.3
Limits of Analytical Parameters

PARAMETER	ANALYTICAL PROCEDURE	LIMIT
PH	Malone Lab	6–8
Alkalinity	Malone Lab	Apply at rate that does not adversely affect pH
Sodium	Agronomy Dept.	Dependent on bases 390 ppm for MSS5 sample
Bases	Agronomy Dept.	n/a Influences sodium

`

The sample labels used are presented in Table D.4. The pH and alkalinity results are presented in Tables D.5 through D.7.

Table D.4
Sample Identification and Source

MDS4	MEXICAN DIRT (SOIL) SAMPLE 4	SOIL ON SITE TO RECEIVE MVVDVCT COMPOST
MSS5	MEXICAN SLUDGE (POWDER) SAMPLE 5	MVVDVCT TOILET
MLS6	MEXICAN LIME SAMPLE 6	LIME USED BY MVVDVCT TOILET

Table D.5
Results of pH Determinations

SAMPLE ID	pH 1st Dilution *	pH 2nd Dilution **	pH 3rd Dilution ***	Suggested pH	Result
MDS4	6.76	6.59	7.4	6-8	OK AS IS
MSS5	7.39	9.22	7.5		OK TO ADD (considering pH**** only
MLS6	12.68	–	12.6	–	Recommend to consider discontinuing use

*1:10 Dilution ratio
**Dilution as indicated in attachment
***Diluted at 1:1 ratio
****See alkalinity section and other tables for alkalinity impact on pH and compost use

Table D.6
Alkalinity Results

MDS4	4.0	1.97 mg $CaCO_3$/g soil
MSS5	277.4	139.0 mg $CaCO_3$/g sludge
MLS6	362.8	909.9 mg $CaCO_3$/g lime

Table D.7
Comparison of Alkalinities of Sludges Versus Soils

TOILET TYPE/LOCATION	Soil pH	Soil mg $CaCO_3$/g	Sludge mg $CaCO_3$/g	Lifetime Maximum Application Rate* tons/acre	Max # of Years can Apply Annual Batch	Sludge Weight per Year Available tons/year
Mexico (Urine excluded/ Lime added)	7.4	1.97	136.1	8.8	20.0 years to 1.0 acre	.44

*These figures are based on pH and alkalinity concerns only and are not the actual recommendations.

Table D.8 presents one of the two most important findings, that the compost must be applied at a very thin application rate (3/32”) to a parcel of land approximately 50 feet wide by 50 feet long to prevent an adverse impact to the soil’s alkalinity.

Table D.8
Compost Application Recommendations
(Based on Alkalinity Restrictions only)

TOILET TYPE/LOCATION	AREA TO APPLY ONE YEAR’S VOLUME OF COMPOST (SF)	COMPOST DEPTH (INCHES)	ANNUAL COMPOST VOLUME (FT^3)
Mexico (Urine excluded/Lime added)	2178 (46.6’ x 46.6’)	3/32	17.0

Tables D.9 and D.10 show that the waste has very little value as a compost, with only 7.09 percent organic matter and with macro-nutrient concentrations of phosphorus, potassium, and nitrogen of approximately 18, 4, and 38 percent, respectively. This results in a PKN ratio of 0.5 to 0.1 to 1. A range of the ratio of PKN needs fluctuate for the agricultural needs of the plant, the soil, season, etc. *Very* approximately, the ratio between the different parameters is a factor of 1 to 2 between the different parameters, i.e. 10:10:10 or 10:10:20. While it is obvious that the waste is not a good compost, Table D.11 shows that the counterpart to that low compost quality is that the toilet is very efficient at removing nitrogen.

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Table D.9
Nitrogen Results
(Components in Compost)

SAMPLE ID	NH_3-N ppm	NO_2-N ppm	TKN ppm	BOUND N* ppm	ORGANIC N %	ORGANIC MATTER %	ORGANIC MATTER IN LOCAL SOIL %
MSS5	184	13	3,150	2,996	94.2%	5.6	7.09

*TKN = Bound Nitrogen (mostly Organic N) + NH_4 + NH_3-N.

Table D.10
MSS5
(MVVDVCT Facility)

MACRO-NUTRIENT	RECOMMENDED APPLICATION RATE (SLUDGE LB/ACRE)	ACTUAL APPLICATION RATE (SLUGE LB/ACRE)	% FERTILIZER REQUIREMENT MET WITH COMPOST	% FERTILIZER REQUIREMENT REQUIRED FROM COMMERCIAL FERTILIZER
P	95461	17261	18.5	81.5
K	408906	17621	4.3	95.7
N	46032	17261	38.3	61.7

Table D.11
Nitrogen Removal Efficiency
TOTAL NITROGEN
(ppm)

SAMPLE ID	URINE INITIAL	EXCREMENT INITIAL	URINE & EXCREMENT INITIAL	FINAL	EFFICIENCY
MSS5 (MVVDVC TOILET)	0	13,000	–	3,163	75.7%

Tables D.12 to D.14 are tables consisting of some data and analysis used in the calculations.

Table D.12
Alkalinity Determinations
(Raw Data)

SAMPLE ID	WEIGHT OF SAMPLE (grams)	WEIGHT SAMPLE + DISTILLED WATER (grams)	pH	Volume Titrant Required to Titrate to Endpoint (mL)
MDS4	0.20	100.40	7.4	0.4
MSS5	0.20	100.20	7.5	27.8
MLS6	0.59	100.58	12.6	>50

Table D.13
Densities of Samples

SAMPLE IDENTIFICATION	DENSITY (KG/L)
MDS4	1.10
MSS5	0.70

Table D.14
Nitrogen Absorbance Readings

SAMPLE TYPE	ABSORBANCE		
-	NH_3-N	NO_2-N	TKN
Blank	0.004	0.003	0.010
Mexican Sludge Sample 5 (MSS5)	0.327	0.212	1.480

Table D.15 is the mass balance performed showing that the alkalinity (calcium carbonate equivalency) is the limiting factor in the application of the waste to the soil collected and analyzed.

Table D.15

Mass Balance

Element	Recommended		In sample			To be added		
	lb/acre	g/acre	ppm	Element g/kg	factor	Sludge kg/acre	Sludge lb/acre	lb. non-limitant
K	60	27240	177	0.177	0.146733	185643.3113	408,905.97207	2.585603524
N	145	65830	3150	3.15		20898.4127	4,6031.74603	55.50660793
P	60	27240	1928	1.928	0.628528	4339.35799	9,5461.14095	11.07538326
Lime						8000 (metric tons/acre)	1,7621.14537	
Cu			1.14	0.00114				0.020088106
Fe			13.53	0.01353				0.238414097
Mn			5.05	0.00505				0.88986784
Zn			2.86	0.00286				0.050396476
As			13.23	0.01323				0.233127753
Cd			0.04	0.00004				0.000704846
Ni			0	0				0
Pb			0	0				0
B			0.41	0.00041				0.00722467
S			256	0.256				4.511013216
Al			0.43	0.00043				0.007577093
Na			256	0.256				4.511013216
Ca			10179	10.179				179.3656388
Mg			631	0.631				11.11894273

APPENDIX E

PRELIMINARY STATISTICAL ANALYSIS OF DATA

SOUR was performed on fresh samples incubated for one week and again on sample to which moisture was added after another five days. If we look at the differences in the results between the first week and the wetted sample SOUR, you might be able to draw some type of conclusions about the effect that added moisture had on the microbiological activity.

After reviewing the data further, I would recommend that the SOUR on a volatile solids basis not be the focus of your argument. Week correlations are shown between SOUR on a volatile solids basis and the other variables. However, the positive or negative correlations tend to be greater when viewing SOUR on a total solids basis and the other variables. However, do not attempt to draw any conclusions from this data, because your data set is too limited. Instead, just focus on the fact that trends observed tend to follow the expected norms for microbiological activity in organic materials. You don't have sufficient data to do reliable statistics, so correlations will have to suffice. You shouldn't have too much trouble finding literature that supports the trends shown in Green and blue lettering below.

Here are some correlations to consider that were quickly :

Fresh SOURVS vs. VS = 0.03 = the fresh samples SOUR on a volatile solids basis had no correlation with the volatile solids content. This is a direct contradiction to the idea you expressed that a single sample may have lower volatile solids content and a higher SOUR than another sample with higher VS. A gram of highly degraded organic matter (humus) may not have as much microbiological activity as 1/10th of a gram of readily available organic material (fresh cellulosic material) when analyzed for SOUR. Perhaps one sample had more dried, less degraded fecal matter than other samples with similar or greater organic contents. You can't tell which samples contained the more fresh organic materials and which ones didn't, or you might be able to make better sense of this information.

Fresh SOURVS vs. pH = -0.10 = little influence of the pH on the fresh sample SOUR on a volatile solids basis, though a negative correlation may indicate that higher pH levels slightly reduce the SOUR on a volatile solids basis.

Fresh SOURVS vs. moisture = 0.23 = increased fresh moisture has little moderate low, but positive, influence on fresh SOUR on a volatile solids basis. This hints at the fact that increased moisture may increase microbiological activity.

This data appears to have little value to any argument you are trying to make about composting toilets. If you can't find trends in the data, the data should be excluded unless you can find some argument that has value to keep the data. SOURVS should not be used.

In data compiled from composting systems, correlations between variables greater than 0.50 are often very high due mostly to the complexity of the interactions that result in any given result and the error involved with sampling and homogenizing of samples for analysis.

Fresh SOURTS vs. VS = 0.66 = moderately high correlation indicates that, overall, increased volatile solids content appears to increase microbiological activity in fresh samples.

Fresh SOURTS vs. pH = -0.55 = increased pH reduces microbiological activity of fresh samples.

Fresh SOURTS vs. moisture = 0.59 = increased moisture increases microbiological activity in fresh samples.

I think the Green text shows the expected trends, so I would largely ignore including the SOUR on a volatile solids basis in the literature because no strong trends were observed.

Some more good trends that should be examined include:

Fresh SOURVS vs. fresh SOURTS = 0.66 = we would expect to see a fairly strong positive correlation between SOUR on a volatile solids basis and SOUR on a total solids basis.

VS vs. pH = -0.65 = higher volatile solids would be expected from materials that had lower pH because much of the Ash content in your composting toilets came from high pH lime or ash, correct? Another way to look at this, as nonvolatile solids increased as ash or lime in the toilets, the higher the pH climbed in the samples.

Fresh Moisture vs. pH = -0.57 = elevated moisture in organic samples under a stable condition would be expected to be near neutral, but when disturbed and allowed to aerate, pH changes do occur. Higher moisture usually indicates the potential for more activity in drier samples which could account for more acidity production. It's hard to tell.

Now, let's examine what happens to trends after moisture is added and the materials are incubated for five days. You determine if these are relevant to your argument or not. You may not want to use this data at all; I wouldn't except to show that moisture reduces air space and overall reduces microbiological activity. Therefore, dry conditions in the composting toilets appear to benefit the degradation process, and too wet conditions may reduce microbiological activity.

SOURVS vs. VS = -0.27 = A slight indication that indicates that as volatile solids increase, added moisture may lead to decreased microbiological activity, which might be expected when pore space is reduced in the materials by water.

SOURVS vs. pH = 0.31 = Elevated microbiological activity in wetted materials may lead to elevated pH, which is often the case in active composting materials. But really, there was little correlation noticed.

SOURVS vs. Moisture = -0.34 = microbiological activity may be reduced by added moisture as pore spaces are filled by water, reducing gaseous exchange.

Overall, the addition of water strengthened the relationship between volatile solids based SOUR and other variables, all explainable by common knowledge about the microbiological degradation process.

SOURVS vs. SOUR TS = 0.85 = Better relationship between the SOUR analyses.

SOURTS vs. VS = 0.21 = adding moisture reduced the predictability of the relationship between microbiological activity and the volatile solids content.

SOURTS vs. pH = -0.03 = no correlation at this point, probably because the initial pH had no influence on the microbiological activity in wetted materials.

SOURTS vs. Moisture = -0.10 = no real correlation.

Basically, the only information gained from this exercise was to show that differences in the materials obtained from the composting toilets was highly variable in the amount and degree of degradation in the organic fraction. Microbiological activity probably increased slightly in those that contained more readily available organic C and decreased in those that did not, though added moisture probably decreased the average microbiological activity.

Any one of the units stated to express SOUR would probably be acceptable, but you would most likely want to use the EPA Biosolids since you are working with biosolids. This is another reason for ignoring the SOUR calculations based on volatile solids. This only confuses the issue more.

Item 3. The values of 0.3 to 1.3 are not allowable limits. These represent a range of SOUR values on a total weight basis that I have observed in stable composted and treated biosolids. The EPA limit for vector attraction is 1.5 mg/g total solids / hour, but this is to reduce the odor threshold.

The EPA probably uses total solids mostly because, with the exception of lime stabilized sludge that doesn't require SOUR, most of the material is organic anyway, and the whole sludge is of interest. In compost, only the organic fraction is of interest, so all materials are gauged on the volatile or organic fraction. On soils and other materials that have a small organic fraction, calculations on a volatile solids basis may reduce variability caused by the non-volatile fraction. In your case, I thought that the volatile solids fraction SOUR might provide data of interest, but again, the total solids fraction SOUR should be used because you are dealing with biosolids, and the entire "sludge" is the focus, not just the organic fraction. Besides, the total solids fraction appears to provide more explainable data.

I hope this has provided some help in working through the mess that is analytical data. There are no real conclusions or true comparisons that can be made without knowing more details about the individual toilets and materials used in each one. And without replication, statistics are not possible. All you can do is look for some kind of trends that might strengthen your argument.

APPENDIX F

SUMMARY OF STATISTICAL DATA

Preliminay Analysis
STATIS TICAL ANALYSIS

	Parameter A	Parameter B	r^2	Correlation Result			Possible Conclusion	Expected	Useable
FRESH SOUR VS before M added									
1	SOUR VS	VS	0.03	**None**			1 gram highly degradable O.M. (i.e. humus) that may not have 1/10th microbial actitvity as 1/10th gram readily available O.M.(fresh celllosic material)		No
2	SOUR VS	pH	-0.10	**None**			pH little influenc on SOUR but negative correlation may indicate that increase pH levels slightly reduce SOUR VS		
3	SOUR VS	M	0.23	Moderately low			Hints that increased moisture increases microbial activity		
FRESH SOUR Total Solids before M added									
4	SOUR TS	VS	**0.66** ?	**Mod.High Overall**	→	↑ VS ↑ Mic.Act.		Yes	Yes
5	SOUR TS	pH	**-0.55**	**Inverse**	→	↑ pH ↓ Mic.Act.		Yes	
6	SOUR TS	Moisture	**0.59**	**Moderatelty High**	→	↑ M ↑ Mic.Act.		Yes	Yes
	Overall Conclusion	:	Microbial Activity increases with higher organic matter(VS),moisiture and decreases with pH						
FRESH SAMPLES :Other Good Comparisons with VS and Moisture									
7	SOUR **VS**	SOUR **TS**	**0.66**	**STRONG**	→	↑? TS ↑? VS		Yes	
8	VS	pH	**-0.65**	**Inverse**	→	↑ VS ↓ pH	**due to Much of NVS in Waste from High pH Lime or Wood Ash in Additive**		
9	M	pH	**-0.57**		→	↑ M ↓ pH	When sample DISTURBED & allowed to aerate **pH changes occur.** increase moisture usually indicates **potential for more acidity production which could account more more activity in drier samples**		
					→				

TRENDS **AFTER MOISTURE ADDED** and INCUBATED FOR 5 DAYS

10	SOUR VS	VS	-0.27		→	Slight indication increased VS & Increased Moisture?? Expected when pore space reduced in the materials by water
11	SOUR VS	pH	0.31		→	Increased microbial activity in Wet Materials and elevated pH -> often in active composted materials but ...
12	SOUR VS	M	-0.34 Overall			**Decreased microbial activity by increased moisture as pore spaces filled with water, reducing gaseous exchange**

~~*OVERALL WATER ADDED INCREASED RELATION BETWEEN SOUR (VS ??) BASED ON OTHER MTLES?? THEREFORE COMMON KNOWLEDGE INCREASED EXPLAINABLE*~~

SOUR TS **AFTER MOISTURE ADDED**

13	SOUR **TS**	SOUR **VS**	$\boxed{0.85}$		→	↑ TS ↑ VS **Better Relation between SOUR Analysis** Analysis
14	SOUR TS	VS	0.21		→	↑ SOUR TS ↑ VS Addition of water, reduces the Predicitability between Microbial Actitity
15	SOUR TS	pH	-0.03	**No correlation**	→	Yet ? Due to initial pH no influence on microbial activity in wet environment
16	SOUR TS	M	-0.1	**No correlation**		

Difference in materials obtained from toilet is highly variable in amount and degree of degradation in organic fraction. Micrboial activity probably increases slightly in samples that contained more readily available carbon and microbial activity decrease in samples that did not have readily available carbon, though moisture added probably decreased microbial activity

APPENDIX G

INFREQUENTLY ENCOUNTERED PROBLEMS IN GUATAMALA DESICCATION TOILET PROJECT

CUADRO No. 5
PROBLEMAS ENCONTRADOS EN EL USO DE LASF

	Ceniza	Humedad	Insectos	Olores	Mal uso
Ceniza	16.7 * 2.6	–	–	–	–
Humedad	2.5 *2.6	3.1 *1.3	–	–	–
Insectos	3.5 *3.9	5.0 *15.6	5.3 *7.8	–	–
Olores	0.3 *0.0	0.9 *2.6	7.5 *0.0	2.2 *1.3	–
Mal uso	1.3 *0.0	0.6 *1.3	1.3 *1.3	0.0 *1.3	2.5 *2.6

Ninguno 37.1% Combinación de tres 9.9%
* Ninguno 46.7% * Combinación de tres 9.1%

* Usuarios irregulares

Códigos: Ceniza= Falta de ceniza; Humedad= humedad en las cámaras; Insectos=proliferación de insectos; Olores= Malos olores; Mal uso= Desconocimiento en el uso

Note: 1) Ceniza = Additive(including wood ASH), 2) Humedad = Water Content, 3) Insectos = Inscets, 4) Olores = odors, and 5) Mal Uso = Lack of Knowledge & Improper Use

Source: Xet, 1988. Modified by Author.

APPENDIX H

AGRICULTURAL ECONOMIC ANALYSIS OF SMALL BUSINESSES THAT APPLY COMPOST

CUADRO No. 8
ANALISIS AGRICOLA-ECONOMICO DE LAS MICROEMPRESAS
QUE APLICARON EL ABONO DE LASF

Micro-empresa	Productores N	Productores %	Cultivo	Producción lbs Anterior	Producción lbs Actual	Incremento: lbs	Incremento: %	Valor Q
1	5	34	Ajo	3,650	5,100	1,450	28	653
	8	53	Maíz	2,850	4,700	1,850	39	444
	2	13	Sin aplicación	-xx-	-xx-	-xx-	-xx-	-x-
2	5	50	Maíz	2,850	4,700	1,850	39	444
	3	30	Brócoli	3,000	4,300	1,300	30	247
	2	20	Sin aplicación	-xx-	-xx-	-xx-	-xx-	-x-
3	4	50	Café	2,350	4,000	1,650	41	743
	2	25	Maíz	600	1,350	750	56	180
	2	25	Sin aplicación	-xx-	-xx-	-xx-	-xx-	-x-
4	1	14	Maíz	350	500	150	30	7
	6	86	Sin aplicación	-xx-	-xx-	-xx-	-xx-	-x-
5	3	43	Maíz	700	1,350	650	42	156
	3	43	Café	2,150	3,850	1,700	44	765
	1	14	Sin aplicación	-xx-	-xx-	-xx-	-xx-	-x-

Notes: 1) Ajo = Garlic, 2) Maiz = Corn, 3) Brocoli = Broccili, 4) Café = Coffee, 5) Sin Applicacion = Without application (compost not applied to crop – control)

Source: Xet, 1988. Modified by Author.

APPENDIX I

MAJOR DISEASES OF LATIN AMERICA

Prevalence, Mortality, and Morbidity of the Major Infectious Diseases of Africa, Asia, and Latin America, 1977–1978

Infection	Infections (thousands per yr.)	Deaths (thousands per yr.)	Disease (thousands of cases per yr.)
Diarrheas	3–5,000,000	5–10,000	3–5,000,000
Respiratory infections		4–5,000	
Malaria	800,000	1,200	150,000
Measles	85,000	900	80,000
Schistosomiasis	200,000	500–1000	20,000
Whooping cough	70,000	250–450	20,000
Tuberculosis	1,000,000	400	7000
Neonatal tetanus	120–180	120–180	100–180
Diphtheria	40,000	50–60	700–900
Hookworm	7–900,000	50–60	1500
South American trypanosomiasis	12,000	60	1200
River blindness	30,000	20–50	200–500
Meningitis	150	30	150
Amebiasis	400,000	30	1500
Ascariasis	800,000–1,000,000	20	1000
Poliomyelitis	80,000	10–20	2000
Typhoid	1000	25	500
Leishmaniasis	12,000	5	12,000
African trypanosomiasis	1000	5	10
Leprosy	Very low		12,000
Trichuriasis	500,000	Low	100
Filariasis	250,000	Low	2–3000
Giardiasis	200,000	Very low	500
Dengue	3–4000	0.1	1–2000
Malnutrition	5–800,000	2000	

Source: Walsh and Warren 1979. Based on estimates from the World Health Organization and its Special Programme for Research and Training in Tropical Diseases, confirmed or modified by extrapolation from published epidemiologic studies performed in well defined populations. Figures do not always match those officially reported, because under-reporting is great.

Source: Okun, 1987. Originally from Walsh and Warren as cited above by Okun.

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APPENDIX J

IMPACT ON DIARRHEA MORBIDITY

Impact of Water Supply and Sanitation on Diarrhea Morbidity in Children

Improvement	Number of Studies	Median of Percent Reduction
Water Quality	9	18
Water Quantity	17	25
Quality and Quantity	18	37
Excreta Disposal	10	22

Source: Okun, 1987.

APPENDIX K

BENEFITS OF WATER SUPPLY AND SANITATION VERSUS ORT

Table 4

Benefits Associated with Major Interventions

Benefits	Interventions		
	WS&S[a]	Immunizations[b]	ORT
Health			
Control of diarrheal diseases			
Curative			X
Preventive	X	X	
Control of other WS&S-related diseases	X		
Improved primary health care	X	X	
Improved nutritional status	X		
Service to health centers	X		
Economic			
Time released for women	X		
Household irrigation & animal watering	X		
Promotion of commercial activity	X		
Support for other sectors	X		
Social			
Improved community organization	X	X	
Improved quality of life	X	X	

[a] WS&S: Water Supply and Sanitation introduced with community participation and hygiene education.
[b] Immunizations: Measles, DPT, cholera, typhoid, and polio.

Source: Okun, 1987

APPENDIX L

TECHNOLOGY SUBSTITION

Figure L.1 A Desiccation Toilet Converted to a Water Bathroom
(Photograph by Armando Galvez)

APPENDIX M

MODERATELY-RAPID ASSESSMENT STEPS

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1) Solicitation by Individual or Community to Exterior Support Group
2) Agreement between Individual or Community and Exterior Support Group
3) Planning, Preparation and Provision of Materials, Labor, and Minimum 10 percent Cost by Individual or Community
4) Construction and Supervision
5) Informal Health Talks at Site of Construction while performing Physical Labor
6) Start-Up of Use of Facilities; Operation and Maintenance Follow-Up

==

7) Waste Handling: Vault Change-Over, Contents Removal, and Start-Up of Second Vault

----

8) Sampling and Analysis
9) Dialogue
10) In-Field Drafting of Report / Quantification of Factors
11) Final Quantification and Evaluation of Factors (Formal Qualitative Report Optional)

==

12) Withdrawal from the Community (see Appendix DD)

NOTE: 1) If the exterior support group is working with the community for a moderately-long period, only steps 1 through 7, plus step 12, may be necessary.

2) If the exterior support group has very little experience with the community (i.e., not present during first five steps), steps 7 through 11, plus step 12, would be necessary. Because the experiential component is not there, the exterior support group would have to rely upon more “hard core” technical and social sampling techniques, and also observation of waste handling activities. For both circumstances, waste handling observation and proper withdrawal are critical.

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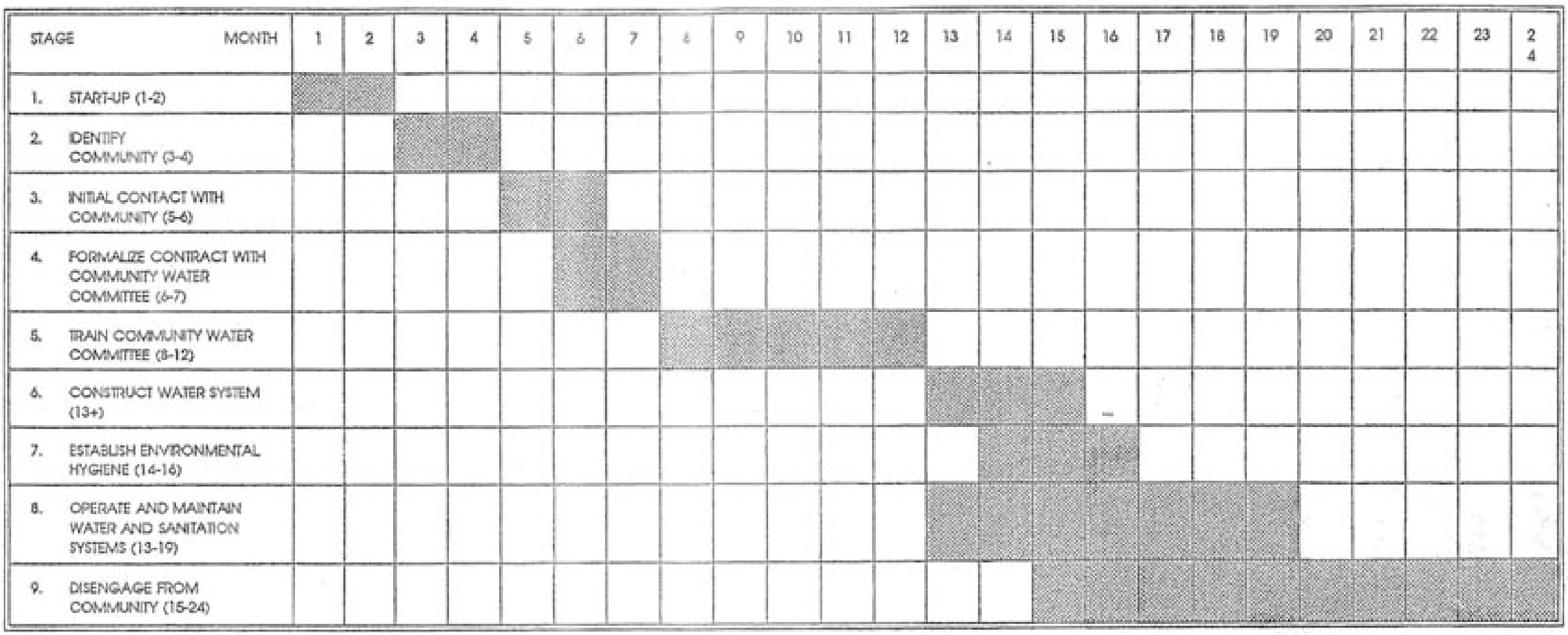
APPENDIX N

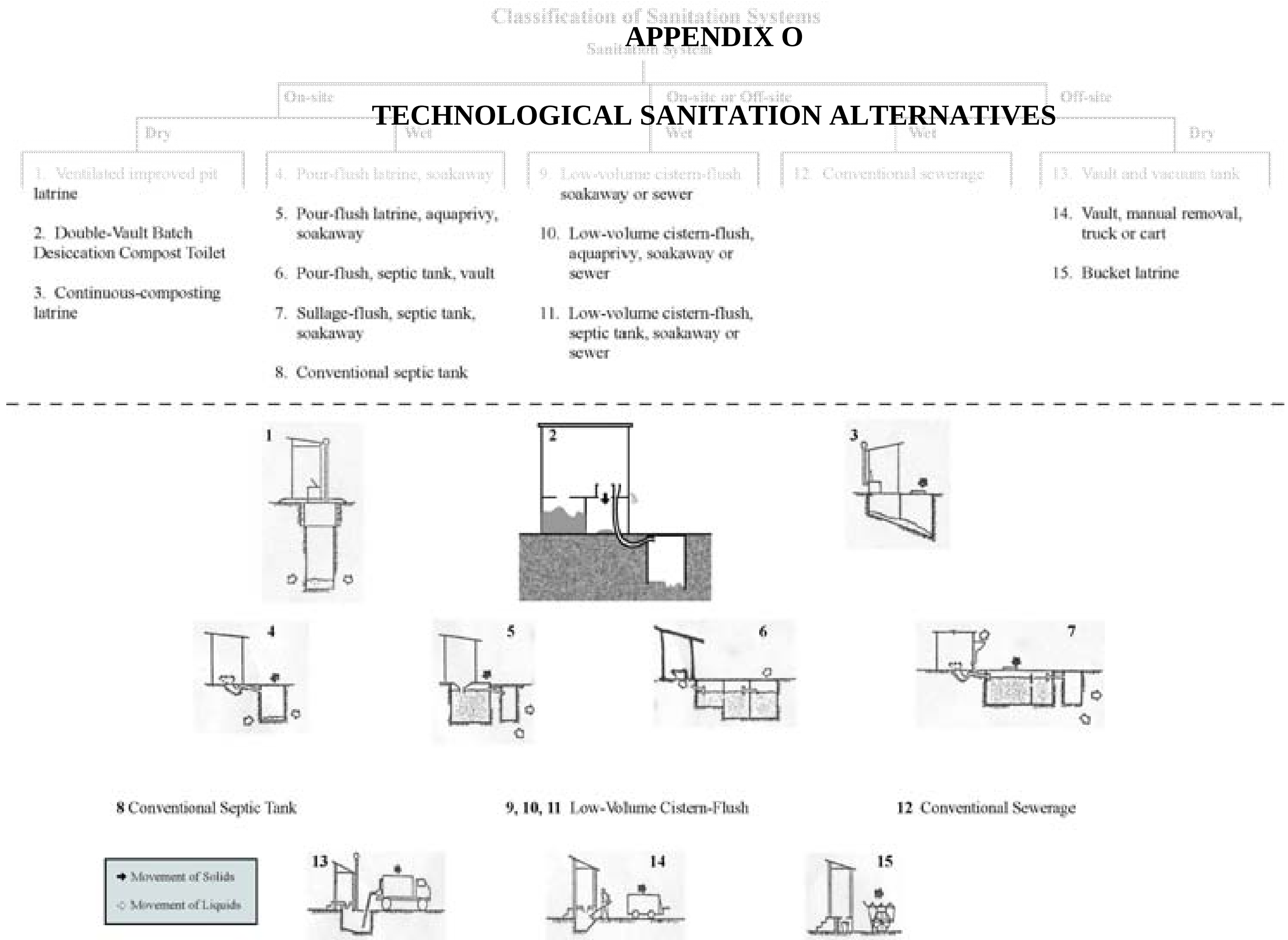
PROJECT CYCLE AND IDEALIZED TIME PERIODS



Source: Yacoob, May and Phillip Roark. *Steps for Implementing Rural Water Supply and Sanitation Projects.* Washington D.C.: U.S. Agency for International Development, 1990

APPENDIX O

TECHNOLOGICAL SANITATION ALTERNATIVES



Source: Camp Dresser and McKee Consultants – WASH, 1983. Modified by Author.

APPENDIX P

ANTHROPOLOGICAL CONSIDERATIONS OF COMPOST TOILETS IN RURAL MEXICO

P.1 Desiccation Toilet

The subject of this work was the diffusion of a compost toilet, invented in 1959 by a Vietnamese doctor, then adapted and introduced in Latin America, and in this case, by the non-profit group, to the community of Sonacala (a fictitious name for protection of privacy), Figure P.1, in Mexico. Figure P.2 illustrates conceptually a traditional Vietnamese double-vault compost toilet (brick and block versions) without squatting version and Figures P.3 through P.5 illustrate actual brick, block, and fiberglass versions, respectively. The Mexican version used in Sonacala used a toilet basin, seat, and urinal for use in the sitting position. The hypothesis was that this toilet was successful and accepted by some of these users. In some ways, technology acceptance is a more significant issue than technological success. This is because technological success, that is, treated waste, is a lot easier to achieve than social acceptance. If the desiccation toilet is accepted, it is easy to make it work. Just because the desiccation toilet is a proven technology, this does not guarantee its acceptance.

P.1.1 Objectives

The principal objective of this report was to define and determine acceptance and rejection, and to determine the influential social factors and indicators that led to the acceptance or rejection to date of the desiccation bathrooms in the community of Sonacala. The issue of technical success,[5] or technical failure,[6] of the desiccation toilet was investigated in the body of this report.

[5] Since technical success of toilets does not guarantee use by the owner, an analysis is needed of both the technical, and the social factors and criteria that contributed to the acceptance or rejection of the toilets and the outside support. Acceptance or rejection of the toilets versus acceptance or rejection of the outside support provided by the developmental agencies must be isolated and both addressed if possible. The technical factors (i.e., ease of construction) that contributed to social acceptance should not be confused with the technical criteria of success (i.e., adequate waste treatment results).

[6] Since technical failure of the toilet, that is non-compliance with regulatory or technical requirements, does not guarantee abandonment, the analysis of both the technical and the social factors that contributed to the abandonment and rejection of the toilets and outside support must also be analyzed. The technical factors (i.e. odors) that contributed to social rejection should not be confused with the technical criteria of failure (i.e., inadequate waste treatment results).

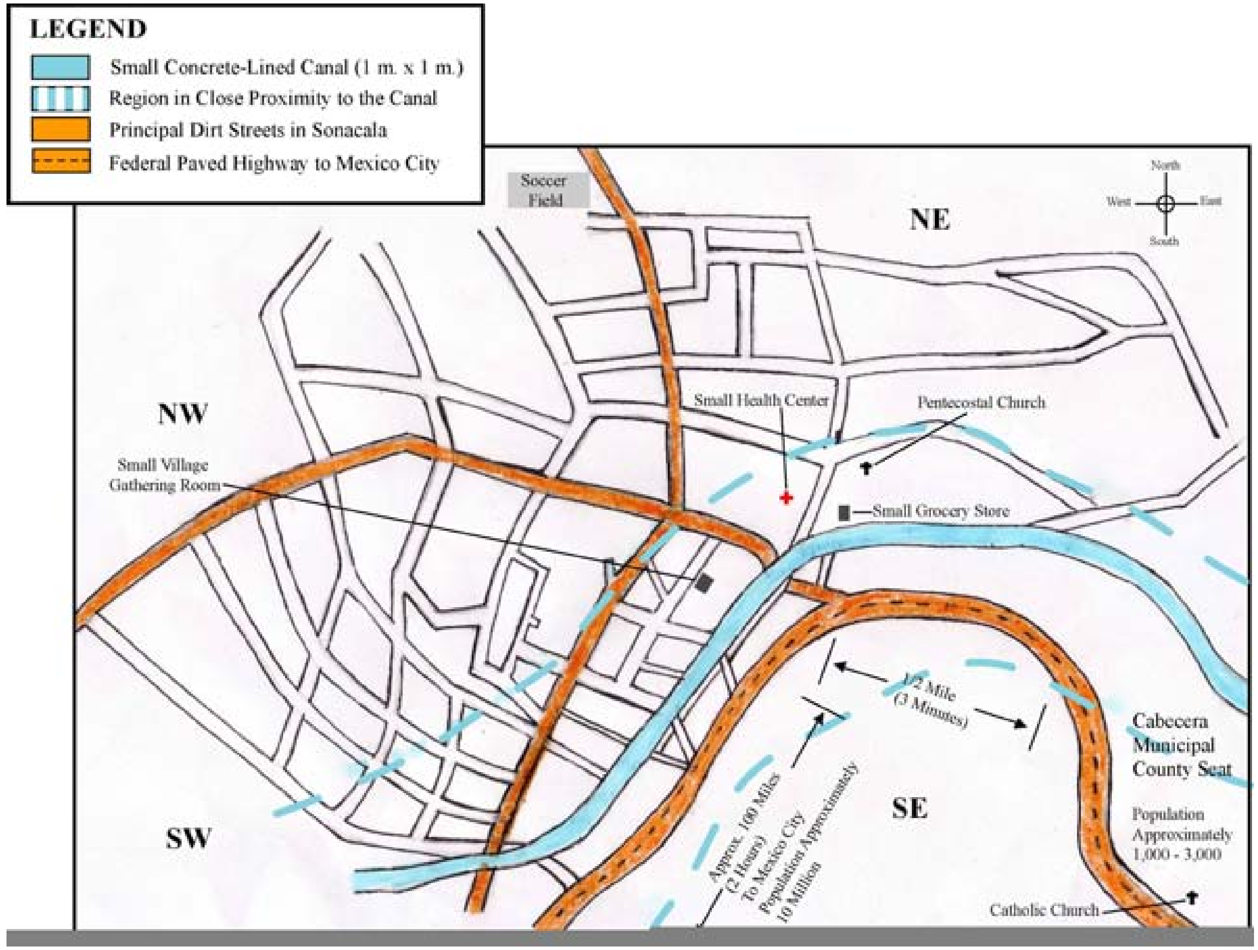


Figure P.1 Community of Sonacala, Mexico (Figure by Joel Geiger)

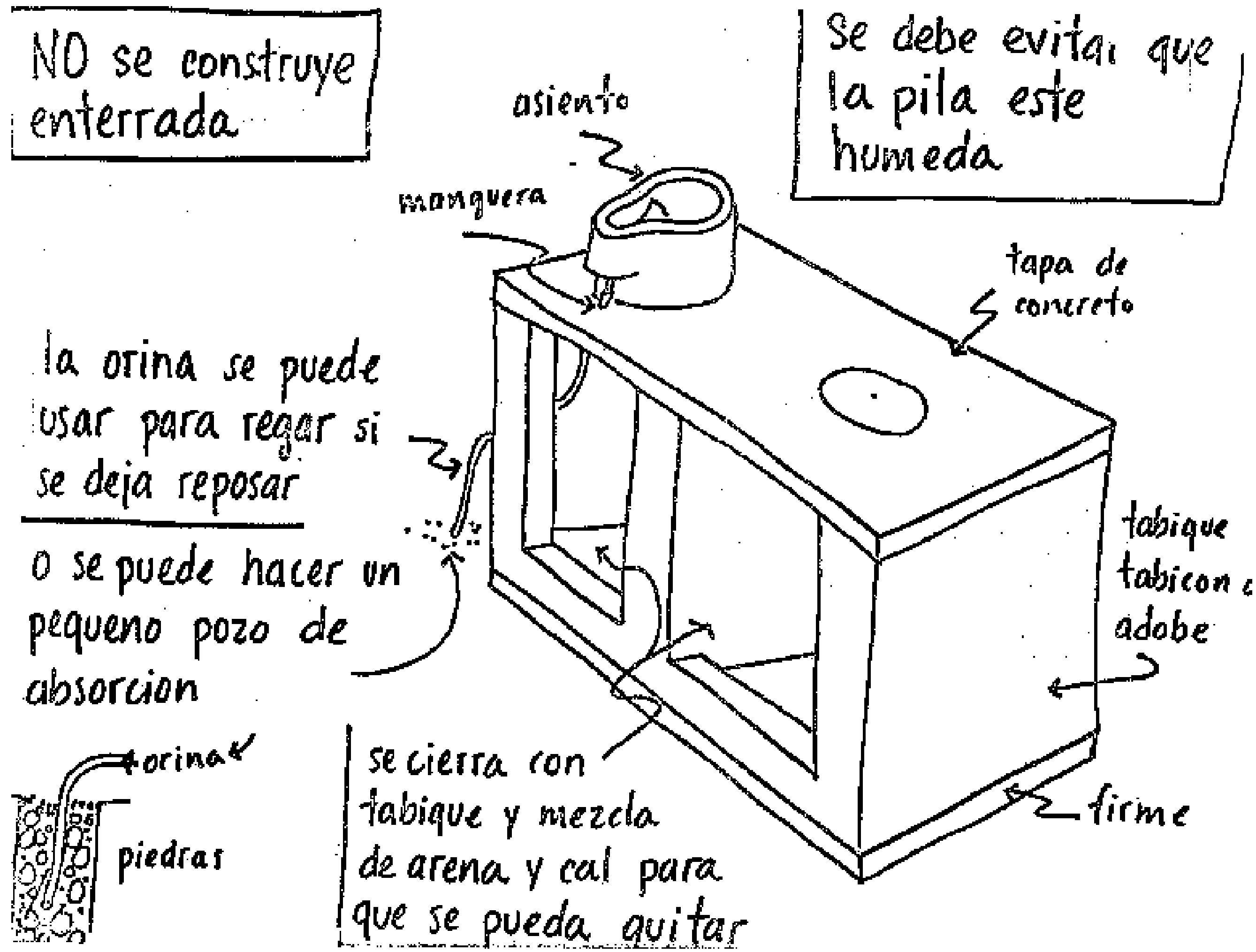


Figure P.2 Conceptual Illustration of Alkaline Desiccation Compost Toilet (Drawing by Cesar Anorve)

Figure P.3 Back of Brick Desiccation Compost Toilet
(Photograph by Joel Roberts)

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Figure P.4 Block Alkaline Desiccation Compost Toilet; Israel Monroy in Background (Photograph by Joel Robert)

Figure P.5 Fiberglass Alkaline Desiccation Compost Toilet (Photograph by Joel Robert)

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P.1.2 Antecedents

An opportunity existed in Sonacala, Mexico, to have a holistic analysis of both technical and social factors that influenced the successful and failed interventions of several organizations in the village's "development" or, better phrased, its path, initiatives, and choices. The objective of the team in their 14-year presence in the village was to provide alternatives and assist the members who chose to participate and solicit support. Sensitivity and incorporation of existing beliefs and behaviors related to health and sanitation were a part of the approach.[7]

A lack of interest and financial support by funding agencies for these types of projects has prevented an analysis of the social factors (Camp, Dresser, and McKee,1983), more than the technical ones. This is also true in the case of this particular village's sanitation project. As foundation funding has decreased with a weaker U.S. economy, contributions to non-profit groups have also decreased. It appears that at times only academia and its students have the interest, time, and resources to support, participate on a long-term basis, and perform extensive evaluations of developmental projects.

Identification and development of such information by personnel with both technical and social backgrounds using the above three vantage points (engineering, anthropology, and a combined approach) has not been funded and appears not to exist, which is true in the case of this central Mexican village. Particularly lacking was an intensive objective investigation of a long-term in-place sanitation project with desiccation bathrooms in central Mexico. The desiccation compost toilet is a new technology whose parent technology was invented in Vietnam in 1959 and later modified and introduced in Latin America. Other work has been done in Sonacala, but investigators were only present in the community for short time spans, and thus could not have a deep understanding of the community.

One group was a governmental agency most probably with a top-down, traditional bureaucratic approach. There were two other organizations that intervened in the community—

[7] The technologies' introduction occurred after the non-profit staff, along with the local health agency, met with the leader of the village. It was discussed if the community was interested in participating in a sanitation program. Rather than this form of solicitation of the community, it was decided that individual participation, through solicitation by the individual households, to the project staff would be the better method of introduction and participation, not a decision by the entire community.

Previous to this meeting, it appeared that the health department with whom the non-profit group was collaborating "picked out" this community as a good candidate. After having worked in another village with a similar method of approaching the community, where there was almost complete rejection of the technology from the beginning and where health promoters "actively promoted" the technology, the program philosophy changed to one based of participation only when individuals solicited the non-profit group or the village leader. This philosophy greatly assisted with technology implementation and acceptance in Sonacala. It was later seen that inadequate follow-up and other issues were reasons for significant decreases in acceptance and shorter life spans of the technology, and it was not the same errors in approach that occurred previously.

one an environmentally-based group that is a proponent of innovation of appropriate technology[8] that actively promotes desiccation bathrooms; the other a business whose motives were assumed to be strictly financial since it manufactured a later fiberglass version of the introduced technology that was purchased and installed by the municipality for a price substantially higher than the cost to build and install the other two versions. The opinions and promotions coming from these two groups may have resulted in biased information that needs to be reevaluated in a very objective way. This biased information and attitude may have projected a view of the reportedly environmentally-friendly toilets more favorable than the reality of their implementation, use, maintenance, and especially state of hygiene. On the other hand, developmental planners and others may have an inappropriately exaggerated, pessimistic view of the potential feasibility of desiccation bathrooms. Regardless, this view appears to be based on real failures to date of desiccation bathrooms in areas where adequate resources and appropriate implementation techniques were not available for their long-term sustainability. Still yet, other sanitation options generally favored, besides desiccation and compost toilets,[9] have difficulties and failures also. The pros and cons continue. Because of the wide disagreement on the on-site technologies' sustainability, consensus-building is needed. It must be accomplished with a well-rounded "peer group" to evaluate the results and establish "the truth"[10] and the standards.

[8] Appropriate Technology is a term coined by E.F. Schumacher (unknown), the author of "Small is Beautiful"—a classic work on technology development for rural developing areas. "Technology with a Human Face" is another classic work on the subject. A criticism of appropriate technology was made in a report by Wytold Rybinski. An analysis of Rybinski's report and the general concept of appropriate technology can be found in *The History of Appropriate Technology* (Bates, 1998).

[9] In most of the literature, the type of technology investigated is called a compost toilet. The author has chosen to rename it an alkaline desiccation compost toilet to overcome misperceptions and problems that have resulted partially due to the name, misleading readers about the toilet's composting capacity. The term compost has been left in the title because there is some value as compost and because this is how they are commonly known.

[10] According to Harry Collins and Trevor Pinch (1993), the word *truth* describes science as powerful, clumsy, and dangerous, and without control can destroy its masters with its flailing vigor. Science is not to be blamed for its mistakes. The mistakes are man's mistakes. The shock comes because the idea of sciences is so enmeshed in philosophical analyses, in myths, in theories, in smugness, in heroism, in superstition, in fear, and most important, in perfect hindsight, that what actually happens has never been told outside of a small circle. (This circle is the circle of recognized scientists who are accepted to be the experts on the technology in question.) In controversies, it is invariably the case that scientists disagree not only about results, but also about the quality of each other's work. This is what stops experiments from being decisive and gives rise to what's called "experimenter's regress."

Because of the multi-disciplinarian nature of this work and the developing science of desiccation bathrooms, a peer group is needed to establish what can be attempted to understand about "the truth" through basically the only process available—consensus. If consensus cannot be achieved, a majority and minority viewpoint will be presented.

P.2 Literature Review—Dual Approach

In international developmental sanitation projects, there are at least two basic components that must be addressed: 1) the technology that is chosen, constructed, and used; and 2) the program and its methodology and/or philosophy that assists in the technology's selection, design, program definition, planning, implementation, and continual re-evaluation. Naturally, these programs often have a formal health education component to them. More sophisticated programs will include what is termed a behavioral change program (Camp, Dresser, and McKee, 1983) (see Appendix Q). These advanced programs may require the participation of a highly experienced rural sociologist or anthropologist. Other programs do not address the educational or behavioral part at all, or attempt to do so very informally and indirectly through talks, ("platicas" in Spanish), that may take place during the construction or operation and maintenance phases. Regardless of the approach, existing belief systems—in relation to health—need to be respected and/or incorporated into the sanitation activity[11] and any posterior program evaluation.

P.2.1 Traditional Latin American Health Beliefs

According to Malinowski (1954), some indigenous communities possess health and hygiene beliefs rooted in spiritual and magical beliefs. These communities do not necessarily have scientifically-based health and hygiene beliefs based on the traditional "germ theory of health." Other indigenous historic health beliefs have been indentified. Hot and cold concepts in South American populations have been indentified (Alchon, 1991). Furthermore, Foster (1967) identified beliefs by some Mexican populations in an equilibrium model, based on the even distribution of heat in the body. This system is a folk variant of the Greek humoral pathology, which is based on the Hippocratic doctrine of the four humors, elaborated on by the Roman physician Galen. According to this system, each of the four humors had its "complexion," consisting of pairs of qualities. Blood was hot and moist; phlegm, cold and moist; black bile, cold and dry; and yellow bile, hot and dry. Moreover, since the three most important organs of the body—the heart, brain, and liver—were thought to be respectively dry and hot, wet and cold, and wet and hot, the normal healthy body was considered mostly hot and moist (Foster, 1967). Local healers (curanderos) and natural medicine clinics are present in some areas of Mexico that appear to cater to the above local beliefs in hot and cold concepts. Further investigation is needed to determine its presence or absence in Sonacala.

In addition to people, medicines, and foods, most natural objects also had complexions,[12] based on pairs of the qualities of temperature and degree of moistness. Illness was thought to be caused by an upset in the normal equilibrium of a person's complexion, due to increases or decreases in his humors, or to other causes. The hot and moist balance of the body varied with individuals, and thus, medical practice consisted mostly in knowing the patient's natural complexion, determining the complexion of the illness or its causes, and restoring the fundamental equilibrium that had been upset. This was accomplished by such devices as diet,

[11] The term "activity" is preferred over program or project. An activity is considered an action initiated by the community, rather than the word "program" which is considered an action on the community by an outside group.

[12] Natural history classification was rooted in this concept of complexions.

internal medicines, purging, vomiting,[13] bleeding, and cupping. At the time of the conquest of America, an extremely complex humoral pathology constituted the theoretical framework for scientific (but not popular) Spanish medicine. The system had been carried to the point where complexions were not only marked by pairs of qualities, but the qualities were graded in intensity on a scale from one to four.[14] In time humoral pathology in America filtered down to the folk level, losing on its way the qualities of dryness and moistness, but maintaining the hot-cold dichotomy, minus formal degrees of intensity of temperature[15] (Foster, 1967). In Latin America, modified humoral pathology continues to be the dominant nonscientific conceptual framework within which health and illness are understood by the "folk," and within which curing practices are carried out. In Tzintzuntzan, Mexico, foods, beverages, herbs, medicines, animals, and humans are characterized by a quality of "heat" ("hot" or "irritating") or "cold" ("cold" and "fresh") (Foster, 1967).

The concept of health also follows the doctrine of humoral pathology. The healthy body is thought to be marked by a preponderance of heat over cold, just as in classical times. Heat may attack the body following exposure to high temperatures or as a consequence of: 1) strong emotional experiences such as anger, fright, envy, or joy; 2) injudicious ingestion of hot foods and drinks; or 3) the emanations[16] believed to be given off by a corpse. Cold attacks enter the

[13] With this model reported by Foster (1967), it appears the quality of temperature is the only one quality that is attempted to be controlled the most and restored to equilibrium. Moisture does not seem to be mentioned as much. However, purging, vomiting, and bleeding are exceptions to this assumption. If those practices were carried out to *remove* excess liquid (the humor quality of moisture), further investigation is needed to determine if diarrhea (a losing of needed moisture) was treated in the opposite fashion (retaining liquid) influenced by this belief system.

It has been reported that some parents in Latin America withhold giving their children water when they have diarrhea, an expulsion of liquid. Further investigation is needed to determine if this practice has any relation to the aforementioned illness theory. From the standpoint of promoting an expulsion, it appears not, because the parent is knowingly doing something they believe will prevent the diarrhea. From the standpoint of retaining moisture, perhaps the theory is related. However, it is believed that the belief system is probably more scientifically-based with the parent's belief system in that they do believe that germs are present and they are the cause of the illness. This appears the case because the explanation provided to the author is that the water is withheld because the parents know or think that the water is contaminated and is the source of the illness and diarrhea. Sometimes this practice results in dehydration and/or death of the child.

[14] If such a system existed in Central Mexico, perhaps a numerical quantification system related to social acceptance factors or toilet success could be based on this system. However, its success in implementation is believed to be highly unlikely. Perhaps what can be learned from it is that any numerical quantification is believed to be highly unlikely. Perhaps what can be learned from it is that any numerical quantification of parameters, et cetera, should be simple. Higher numbers such as a 10-based system (1 through 10) or metric system using 1,000s would probably complicate matters. A system based on 1 to 4 or even 1 to 3 would appear more appropriate. For example, 1 would be untreated, 2 would be partially treated, and 3 would be completely treated.

[15] It appears that Foster (1967) is referring to the fact that the system of categorizing the quality of temperature was changed from a system of 1 to 4 to just plain hot and cold.

[16] It is noteworthy to consider if community members may believe that the desiccation bathroom or its compost could release harmful hot or cold emanations. Also it should be examined if the desiccation process is seen as a

body in the form of air, from exposure to cold water, from stepping barefoot on a cold floor, from contact with iron or steel, or from careless use of cold foods and drinks. It is believed that more weapons are needed to fight cold than to fight heat, since the normal state of the body is warm (Foster, 1967).

Curing techniques are also influenced by the humoral system. For people in a state of temporary excess heat, health measures are primarily preventative. For illness caused by the invasion of the body by abnormal amounts of heat or cold, remedial action must be taken. For example, "deposiciones," a medium-serious diarrhea, may be diagnosed as caused by cold (rather than a microbial infection). Accordingly, the patient may be given a tea made of hot herbs, "cinco llagas y cenicilla." Finally, most informants believe that all strong emotional experiences, such as fright, jealousy, envy, anger, pleasure, embarrassment, and grief, are hot and can cause illness. The principal named diseases believed to be caused by emotional experiences are *bilis, tiricia, muina, chipil*, and *mal de ojo* (evil eye). The first four strike the person who experiences the emotion, and in the last, a child is the victim of envy (Foster, unknown).

P.2.2 Current Health Beliefs in Latin America

Some adaptation of the system has occurred. The humoral pathology incorporated indigenous medical beliefs into the simplified Spanish system. Fright and the other emotionally derived conditions previously described all appear to be entirely or principally American rather than European in origin. The process of accommodation continues. Vicks Vapor Rub and aspirin, for example, are classified as hot, but Milk of Magnesia is cold (Foster, 1967). A further explanation of current health beliefs in some Latin American communities can be found in the publication *Donde No Hay Doctor(2007).*[17]

The possible existence of the systems, previously cited above by Foster (1967), in Sonacala was attempted to be identified through the interview process and dialogue with local professionals. The effect of these systems' classification by temperature, health and illness theories, and associated curing techniques was accessed in order to determine how they may have influenced the individual's acceptance of the desiccation bathrooms and the individual's motivation, or lack thereof, to use them for health reasons. From the perspective of the above traditional belief system, the toilet's use, the operation and maintenance, and the individual's perception of the toilet's success and the potential side effects were evaluated. The other possible extreme is that the Sonacala villagers never had or had abandoned traditional beliefs. They may also have already accepted the "modern-day" scientific-based germ theory of illness. Although the western-based belief system is the less romantic of the two options, it is a definite possibility.

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preponderance of heat (hot compost) over cold (cold germs). Perhaps that conquering of "heat" over "cold" could be incorporated into an educational and/or behavioral change program.

[17] Both English and Spanish versions of this book are available.

P.2.3 International Literature Review on Health, Hygiene, and Sanitation

Additionally, an extensive review of the Human Relations Area Files (HRAFs)[18] database for various cultures worldwide, including Mexican and Latin American ones, was conducted. Various beliefs, practices, and attitudes in relation to health, hygiene, and sanitation were identified. Although some of these cultures are from areas outside of central Mexico, this list of potential social factors was used as background knowledge of general belief systems, practices, and attitudes. This background assisted the author and can assist others in detecting, evaluating, and understanding potential beliefs. It was beneficial to have a broad knowledge of various health and hygiene belief systems and sanitation practices in order to be more capable of identifying specific ones in the culture and geographic area of interest. It was determined that an investigators' review of the HRAFs provided him with experience without having to do field work. Although it is not sufficient for investigations, it was a helpful practice to prepare investigators prior to fieldwork. A methodology developed based upon HRAF procedures can be found in a prior draft manuscript of Bates (1999). A broad list of social factors from these worldwide cultures was developed in both categorical format (see Appendix R) and by individual factors (see Appendix S).

P.2.4 Behavioral Change and Health Education Programs

Once the health and hygiene belief systems and current sanitation practices have been identified, behavioral-change (Yacoob, Raddy, and Edwards, 1992) and health education programs are sometimes designed to assist community members in implementing necessary complementary hygiene and health changes in order to make a comprehensive and complete improvement in health (i.e., hand washing, food preparation and storage, water supply protection, and housing improvements). This is called the "software" (Camp, Dresser, and McKee, 1983) of sanitation programs by some, which is outside of the scope of this report. Regardless, the health, hygiene and sanitation beliefs and practices that influenced the acceptance or rejection of sanitation technology were evaluated as social factors. An attempt was made to develop a list of social factors specific and potentially applicable to Sonacala resulting in a "Sonacala-Mexican social factors menu list." This list was difficult to elaborate. In the end the principal social factor or indicator of indigenous health beliefs was the use of natural medicine. A list of over 100 factors was narrowed down to just a few; although more than this was salvaged from the social factor literature search. There was a long list of social factors, however, almost all of them were in relation to program aspects, planning, design, implementation, and evaluation. Those are demonstrated below in Appendices Q through S. The factors that ended up on the social factors list used in the interview process were in fact more of what could be called technical factors, with a sociological component. The investigation had to

[18] Human Relations Area Files is an extensive database of ethnographic accounts, presumably mostly by social scientists of cultures worldwide. It is catalogued both by region, then culture (i.e., Mexico Tarahumara Indians), and also by key subjects (i.e., sanitation).

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be, and was, grounded in science (Rusch, 1993). This was logical because the impoverished Mexican people are more interested in practical matters and ideas that assist them rather than philosophical constructs (Monroy, 2002) ("rollo" in Spanish, translated as "boring" (probably boring nonsense). Some of those combined technical-social parameters were odor, insects, fear of contamination and fear of waste.[19]

Also, the above factors can be evaluated by others for the inclusion into a behavioral-change and health education program. With this software (or, better yet, software code) in place the "hardware" of sanitation projects and activities, that is the technology and its selection, can be better addressed in future sanitation projects in Central Mexican communities similar to Sonacala.

P.2.5 Current Status of On-Site Sanitation Models and Related Work

Currently, there exist several approaches that assist traditionally-educated project managers and initiators (regulators, promoters, health workers, medical staff, planners, engineers, designers, technicians, et cetera.) in project planning, modeling, intermittent review, and final post-project evaluation of the determination and recommendation of the potential appropriateness of various on-site sanitation technologies for impoverished rural[20] communities. These types of approaches, if to be used, must be implemented in coordination with the anthropological technique of triangulation. Triangulation's ethnographic[21] approach must be used to identify the inputs into the model. Another perspective is that an ethnography completely replaces the traditional modeling and planning effort (particularly the social aspect and technology-selection part). As a compromise to both the technical and the social approaches, the intermediate solution would be an ethnography in conjunction with a preliminary engineering feasibility study. For the technology selection aspect, a simplistic approach such as Camp, Dresser, and McKee's (1983) algorithms, sanitation tables, and diagram[22] or Bates and Roy's (1984) on-site sanitation tables. The tool that is perhaps missing in the design community is a manual approach, as opposed to a computerized one. Some type of simple checklist that quantifies the factors is likely to be one that can easily be implemented and understood in the field.

In reference to the sanitation technologies there exist basically three sanitation technologies that are used in this region. In addition to the desiccation toilet, the traditional pit latrine and the conventional waterborne toilet are the other two options. The pit latrine's advantage is its simplicity, low cost, and familiarity, while its disadvantages are its difficulty to

[19] According to Jean Robert (1988), a French writer on innovative technology, he believes that people are afraid of their waste, hence the reason for the popularity of the waterborne sewage systems which flushes their waste away.

[20] This study is limited principally to rural areas where there usually are minimal economic resources with a small or non-existent cash economy and limited infrastructure and services.

[21] An ethnography is an intensive investigation of a single culture that includes a significant field component.

[22] Camp, Dresser, and McKee (1984) published a set of sanitation tables and/or aids for technology selection, which Bates and Roy (1984) later used to develop their own tables.

excavate in rock terrain, associated strong odors and undesirable visibility of the waste, and potential environmental pollution. The waterborne toilet's advantages are its ability to discharge waste off site, perceived lack of odors, and the use of water—a user preference—with the system. Its disadvantages are that it requires water, is difficult to excavate, and its high cost.

P.3 Investigators and Their Limits

The investigation team was comprised of four members, one each from the following four areas: Mexican health department "health promoter," desiccation toilet promoter, sanitation engineer, and non-specialized worker. Limits of investigators were considered as outlined here. The health promoter at times perceived issues from a government employee's viewpoint; however, his relationship grew when his collaboration with the development group was initiated in 1988. Also, his tremendous listening skills and compassion for the community assisted him tremendously in overcoming this tendency. Additionally, he was a "follower" not a leader so he tended to follow suit as opposed to challenging method. The sanitation engineer was a Catholic Christian, a non-profit group employee, initially focused on health-based approaches, and had a conventional engineering background with western influences. He had a slightly aggressive communication style, was a leader/abstract/creative personality profile type, and had a limited understanding of local culture. He initially had a goal of bringing about change to the community. The engineer's training in the social sciences consisted of works in cultural anthropology of Latin America, rural sociology, and a historical study of appropriate technology analysis. As an undergraduate, the engineer also had academic training in political science, including Latin America, history of Latin America, and social work. Although this Catholic engineer worked in a community with an approximate equal mix among secular, Catholic, and Christian evangelic populations and was funded partially by the Catholic Church, he and the non-profit group had a goal and adherence to a non-religious, non-political, grass roots approach.

The Mexican health promoter and the sanitation engineer helped each other to overcome their limitations and forged an intense partnership dedicated to assist the community in appropriate ways and with appropriate techniques. They became "joined at the hip" and rarely left each others' side while in the community. The engineer depended on the promoter's tremendously advanced listening skills and the promoter was open and directed by the engineer's creative, imaginative skills. They became a partnership.

The desiccation toilet promoter was just promoting the desiccation model. He had a preference for that model, as did his architectural step-brother who was a well-known innovator of appropriate technology and who had ties to or followed the guidance of such Mexican thinkers as Gustavo Esteva, Ivan Illich, and the French writer Jean Robert. Although desiccation bathrooms were his preference, if not sole choice of sanitation technology, he was sensitive to villagers' wishes to participate or not. He was intuitive and compassionate. He earned part of his livelihood from the sale of desiccation toilet basins that he manufactured and his step-brother designed and innovated with a Mexican university. He had a tendency for the promotion of environmental values. Even with these facts, he followed the philosophy of the program's approach of participation by invitation only and did not coerce or force his values on community members. Also, he had limited frontline work with the community and had a very non-aggressive personality style. Last of all, there was little known about the non-specialized worker. He was selected by the desiccation toilet promoter and was only present in the community for a two-week period during sampling. He had a slightly aggressive style but was very jovial and had a great skill of lightening the atmosphere with a joking style and charismatic way, using a good smile and laughter which relaxed villagers. During one interview, he and the sanitation engineer were rightly accused of "rapid fire" questioning of one community member. After that slap on the wrist, they both are believed to have made a communication style adjustment. Overall, the team appeared to meet the criteria of multiple team members, according to the approach of Beebe (unknown), the author of the rapid assessment technique discussed further below.

P.4 METHODOLOGY

There were two principal methods used to collect and analyze data. The first was triangulation and the second was consensus-building. The theory and approach of these methods are discussed below.

P.4.1 Triangulation

The anthropological technique of triangulation was used to analyze the events that transpired in Sonacala—to tell its story. This can be considered a common-sense approach to analysis of social situations and people. Other techniques including statistical analysis (which attempts to statistically correlate individual factors and results), and modeling in program planning, execution, and analysis, have their limits. Attempting to mathematically correlate social factors and modeling human behavior removes them from their context (Richardson, 2003).

Specifically, a goal of triangulation was to accurately identify the knowledge, attitudes (including motivations and expectations), and practices of the community. Triangulation is being defined as an approach that takes into consideration three sources of information that become "the 3 points of the triangle" to analyze the information. The triangulation analysis looked at both technical results as well as social factors investigated to determine their influence on success and acceptance, or failure and rejection, of the desiccation bathroom and its use. The triangulation provided confirmation or affirmation of one of the two possible extreme conclusions by "triangulating" three sources of information: 1) the viewpoint of others who have investigated similar topics, accomplished through a literature review; 2) participant observation by the author, which are firsthand observations of the community, the users, and the technology; and 3) key informant consultation, which is the obtaining of information and perspectives from key people in the community (informants) who provide an insider perspective to the community, the users, and the technology. The technical results were factored into the triangulation as an outsider "professional informant" consultation. To balance this exterior viewpoint, the technical viewpoint and technical standards of local technicians were incorporated also. Combined, they provided valuable insights into the actual technical processes occurring in the decomposition process through their operation and maintenance observations and the technical results. The local

Mexican technicians and users provided a different perspective and belief system of "effluent standards" than say EPA standards. Just as U.S. citizens hold different viewpoints from this and other regulatory standards, perhaps even more so will Mexican individuals.

Below, a discussion of the above three aspects of the triangulation technique is presented. Although each aspect is discussed separately and the discussion may appear to separate the three tasks out chronologically and categorically, this should not be construed to indicate that the triangulation process is so formal, rigid, and separated in time. In reality, the three triangulation techniques are intermixed in time and perhaps in other ways. Regardless, for the sake of organization, their separate description follows.

P.4.2 Triangulation's Literature Review

The objective of the literature review, from the viewpoint of the triangulation technique, is to assist in refining goals, establishing methods through evaluating, learning from what others have accomplished previously, and evaluating results. A confirmation of the conclusions of participant observation and informant consultation with the perspective and knowledge of those previous investigators is the first step of triangulation. This is a must to ensure the current investigation makes sense with the overall known current knowledge to date.

P.4.3 Participant Observation

An oversimplification of participant observation may be considered practical experience with the community. Some think of it as the cultural anthropologist sitting on a rock in the community watching the villagers and the community activities and recording her observations in a journal. The formal definition of participant observation is that it is a research method that entails: a) living among a group of people, b) observing their daily activities, c) learning how they view the world (worldviews), and d) witnessing firsthand how they behave (Howard, 1996). Only through significant participant observation of various community activities can an outsider get into the head of the villager and put the mindset of the villager on long enough to attempt to understand, analyze, and document the limited (perhaps only one particular item under investigation) part of the villager's total life. That one item must be put in context with the total life of the villager. For the sake of organization, the actual collection of social factor information from each family was considered part of the participant observation activity, was elaborated in that section, and will be directed by its methods. The method used to collect data under the participant observation task as well as the informant consultation task will be discussed below.

P. 4.3.1 Limits of Participant Observation

Although participant observation provides a lot of insight and answers a lot of questions, an outsider (foreign investigator in this case) can never fully understand a foreign community, its inhabitants, and the intricacies of its languages. Even with participant observation, dialogue with known community members, and reading what others have learned, the local perspective can still not be gained completely.

Furthermore, outsiders will not be able to accurately understand nor obtain information from some of the community members with whom the investigator had no close or specific relationship, rapport, trust, and/or openness with because of limitations of both parties. In the case of Mexico, in the village of Sonacala, this communication impasse existed. Information gained directly from these community members in typical questioning techniques often was not accurate. Possible reasons for the inaccuracy were because community members: 1) tell you what they think you want to hear because of their desire to affirm, be agreeable, be submissive, or avoid conflict, 2) do not tell you the truth because of suspicions of your intentions, 3) may have an agenda, 4) have a different perception of their own, 5) do not possess an understanding of the question or topic being discussed or have a misperception of it, or 6) do not want to appear unknowledgeable, ignorant, or feel embarrassed as a result.

P.4.3.2 Need for Direct and Indirect Approaches

Accordingly, there are two solutions to better ensure that accurate information is obtained: 1) appropriate information gathering techniques for direct inquiries (i.e., individual dialogue-type interview and focus groups) as participant observation techniques, and 2) indirect information gathering techniques themselves (i.e., informant consultation with local villagers who already do have an understanding of their fellow villagers. Another indirect method by investigators and local members is simple observation of community members' actions, words, and emotions.

P.4.3.3 Field Data Collection Participant Observation Approaches

There are several particular approaches to carrying out the participant observation method. Summarized in two steps the participant observation method calls for 1) personal experience living in the village among the people, observing their daily activities, and witnessing firsthand how they behave, and 2) learning how they view the world.

The above summary implies that there is: 1) an experiential portion to participant observation, where one learns by passive and active participation and observation (indirect and direct), and 2) a probing part where one learns through inquiry (direct). For this first experiential step of participant observation, there is only one known approach to accomplishing this task whereas with the second inquiring step, there are at least three approaches. The one passive and three active approaches are as follows, respectively: 1) Simple Observation (direct and indirect), 2) Survey Questionnaire (direct), 3) Dialogue-Type Interviewing (direct), and 4) Focus Groups (direct).

P.4.3.3.1 Simple Observation (Direct and Indirect Approach)

Simple observation is as straightforward as it sounds, although it is by no means easy. It takes perseverance to live under conditions different than one is accustomed to living, to be open-minded, and to have the ability to view the world in a different way. These tasks must be accomplished without being judgmental, and with the patience to wait and learn.

There are some cultural issues, in particular, culture shock and culture sensitivity that have to be handled appropriately by the foreign investigator. This shock is an unexpected and unanticipated surprise to the investigator concerning the activities and behaviors that he is observing. Sensitivity to the culture is required to prevent inaccurate judgments, interpretations, conclusions, and criticism and to accomplish the process of understanding the culture. The behavior of the community members may at times be contrary to what they are telling you, and in some cases the behavior will be the more accurate indicator of the person's real belief and his cultural values. For this reason in general (and in this particular case as to the reasons for acceptance or rejection of the desiccation bathrooms), the investigator cannot focus solely on the words of the community member. Accordingly, simple observation without any dialogue with community members is a must. The author and a local group of investigators have made simple observations of the community members over the last fifteen years.

The last of cultural issues (and influences) that must be addressed is cultural re-entry. Cultural re-entry is a process by which a foreign traveler (the investigator in this case) must readjust to his way of life to live consistently in the society, while maintaining an understanding and acceptance of the new culture at least for his professional work, if not his personal life. Sometimes in the cultural re-entry, the foreign traveler is influenced by other significant people in his home country. He is tempted to reject his new foreign perspective when once again influenced and confronted by the norms and standards of his own culture upon return to it.

P.4.3.3.2 Survey Questionnaire (Direct Approach)

For both participant observation and informant consultation an appropriate information gathering technique is required. Formal questionnaire techniques are very tempting partially because of the thoroughness of the information-gathering tool—the questionnaire—which is well thought out in advance. It gives the investigator a sense of security that she will gain all the required information by asking all the correct questions. It serves also as a guide during the interview that prevents the interviewer from forgetting any questions. It also tends to direct the conversation in a predetermined way if the questionnaire is followed strictly.

Its advantage is that an abundance of quantitative information can be gathered very quickly. Because of the limitations of this method that will be explained below, this approach was not used. Only certain types of questions that are more concrete in nature can be used, such as whether or not an insecticide or certain type of additive was used in the toilet.

Although the questionnaires may cover all or most of the items of importance, various investigators have reported that the answers are sometimes, if not most of the time, not accurate or complete. Some of the reasons for this have been discussed above. In a formal manner, information can be gained with statistical sampling and analysis through knowledge, awareness, and practice (KAP) studies. KAP studies are conventional socioeconomic surveys that focus on quantitative formal interviewing, which uses the questionnaire discussed previously. According to some investigators, this strategy appears to no longer be favored. Because of the advantages of questionnaire-type surveys, some of its elements were incorporated into the more appropriate dialogue-based interviewing. The disadvantageous elements of the questionnaire were avoided.

P.4.3.3.3 Dialogue-Type Interview (Direct Approach)

Strategies emphasizing more direct and more focused data gathering based on a dialogue between planners and community members are more favored than the formal interviewing KAP study approach. This dialogue-based approach is essential with general community members. Use of open-ended questions is necessary also for most information desired. Direct yes/no questions could possibly be used with informants but not as a general rule with general community members. Dialogue makes the community member comfortable and generates trust and openness with the investigator.

The dialogue should be a naturally-flowing conversation in which active listening could be used to affirm to the community member that he is being heard and understood. Affirmation by the investigator of key information spontaneously volunteered by the community member could naturally steer the conversation on to topics that are on the investigator's "list of questions" and part of his area of interest. The direction the interviewee takes will more likely be real experiences, beliefs, and sentiments of his and accordingly will be valuable information.

In "good" conversations there is a give and take, an ebb and flow, in which both parties respond to each other and share equally in talking and listening. It is sort of like a dance in step where each party moves to the rhythm of the other and neither steps on the toes of the other. This is the ideal. In an interviewing situation, the interviewer may have to be more forgiving of the interviewee and play more of the role of active listener and facilitator.

The strength of this approach is its spontaneity, fluidity, and responsiveness to the interviewee. In this project, the strength of the questionnaire (structure and comprehensiveness) has been incorporated without introducing its rigidity and user non-friendliness. This has been done by development of a group of graphics representing points of discussion rather than written questions. These graphics, demonstrated in Figures P.6 and P.7**,** are less threatening to the interviewee than the traditional questionnaire.

These cited social factors, that naturally came up in conversation or were volunteered by the community member without prompting by the investigator, might well be the most significant social factors that can be relied upon. The converse could be true also. If the investigators identified social factors are not spontaneously mentioned by community members that might be an indicator that they are insignificant or not major factors.

Finally, as mentioned above, the investigator cannot focus solely on what the community member says about the topic of discussion, that is, toilet acceptance. What she says must be put in context. Although sometimes what she is telling you may appear contrary to her behavior, it in fact may not be. The logic of behavior is contextually and locally determined. To an insider, the behavior makes perfect sense. Also, what was logical behavior today, may not be tomorrow.

Ideally, long-term participation in the community and dialogue with the community members and informants is the traditional approach to ethnographic work. Typical time frames traditionally considered sufficient are months to years. Since these time frames are not available, investigators used "moderately-rapid appraisal techniques." Additional graphics for the technical and social factors, which are an important portion of this technique, are discussed further below.

P.4.3.3.4 Focus Groups (Direct Approach)

Focus groups are a structured way to gain information from multiple people in a short period of time. The group dynamics' aspect of the process triggers thoughts, feelings, and information from one person upon hearing comments from another. It generates dialogue between community members where they sometimes agree, disagree, or maybe have no set opinion. In this technique, someone must be available to take notes during the session or the session must be tape recorded and documented later. The peculiarities of the community must be taken into account when deciding whether or not and how to conduct focus groups. The makeup of the focus groups, consideration of compensation for participation, and method of selection of members were all taken into consideration. Because of dissention between community members and "heated discussions" the investigation team, who did initiate this step, had to abandon this technique.

Of the three triangulation methods above, the two general category techniques of literature review and participant observation (both direct and indirect) have been discussed. The former is an in-house technique, and the latter is a field technique. The third type of field triangulation technique can be used for both direct and indirect information gathering. This third triangulation method is informant consultation that is described below.

P.4.4 Key Informant Consultation

As mentioned above, because of the limitations of the literature review and participant observation, indirect methods are needed to obtain information about villagers from a third party. A local expert is needed, known to anthropologists as a key informant or a "folk anthropologist." In Central Mexico, they are called "personas que saben" ("people who know" or perhaps a better translation, "persons in the know"). An informant is a person who is believed to have an accurate understanding of the knowledge, attitudes (and motivations), and practices of the community and its members.

Consultation, through dialogue and questioning of the informant, was planned as follows: 1) if the informant was also a desiccation bathroom owner, the general dialogue conducted with him would be concerning his personal experiences with the toilet (direct method); 2) the informant's knowledge and perspective of other community members and the desiccation bathrooms was to be explored also; and 3) other key areas of interest were to be explored, that are either more theoretical in nature ("en las nubes" meaning "in the clouds"), complicated, or sensitive. It is here that sensitive issues must be or can be handled appropriately with the informant. Topics that were attempted to be covered were local health beliefs, political and religious influences, health improvements, cultural issues, and personal or family relationship problems.

Ideally informants were to be picked from a judicious and practical standpoint. Individuals who appear to be neutral to and respected by the community were to be prime candidates. Someone who had an understanding of the desiccation bathrooms (but was not a zealot) and had some social skills would be sought out. Someone with knowledge of the history of the community, its members, and the sanitation project would be important. Alternatively, separate informants could be used as a check on the primary informant's opinions and for miscellaneous tasks. At least one consultant each would be obtained who had a favorable and non-favorable opinion, of the desiccation bathroom. This would be consistent with the approach of the next method discussed—consensus building—where there is a majority and minority viewpoint presented, if they are different. In the end, a single informant was used to assist with all the data collection for the sake of consistency. He was the village leader, a low-income farmer, minimum formal education and was a past paid local contact of the U.S. non-profit agency. Two other informants were sought. One could not be located and the other appeared to be too busy. The informant was not able to supply as much quantity and quality of information as desired.

Once information from all three aspects of the triangulation is gathered, the success and acceptance of the desiccation bathroom was analyzed and determined by the author. Next, consensus with the peer review and the academic committee members was accomplished. Re-consultation with informants, after outside consensus building, would be beneficial to clarify issues, factors, and conclusions. This could be done in a reunion to disseminate results or as a second adventure.

P.4.5 Consensus Building

In areas of new technology there often does not exist long-standing accepted standards. Also in fields, such as international on-site sanitation, that cross academic, professional, and geographical lines, the perspectives from the different pertinent fields and personnel are necessary to make holistic, accurate determinations. In these cases, an approach called consensus building is necessary. A peer review committee can be formed to gather such perspectives from the appropriate disciplines. Through the democratic-committee process, consensus would not necessarily be able to be achieved. Where general consensus cannot necessarily be obtained, resolution of such conflicting perspectives will be resolved by presentation and incorporation of a majority viewpoint and dissenting opinions.

The author's task was to pull together majority views on particular disciplines (i.e., sanitation, composting, rural anthropology, international community development, implementation approaches including traditional "outside" project planning versus grassroots approaches, and analytical techniques such as modeling and triangulation) from small, separate groups of experts. The author was the prime facilitator and through this process developed expertise to ascertain "the truth built on consensus" on the subject of this report. Since he and he only, had the benefit and vantage point of having had the "mindset" and experience with all informants and experts, he became very knowledgeable on the topic. This would be a very unique contribution to the academic, scientific, and professional realms as a result on this engineering science approach, where multiple disciplines are incorporated. Considering the breadth (long-term basis of 14 years of field work) and the scope (multi-discipline—engineering, anthropology, and linguistic), its uniqueness was be more based in reality than any other projects on this report's topic.

Ultimately, the author's primary and secondary task would be to determine potential required technical and social factors in the selection, successful implementation and use, and analysis of appropriate on-site sanitation technology and programs. On the other hand, it would be an additional objective to determine the technical and social factors that would cause failure (the failure points) in the improper selection, or failure of sanitation technology use, programs, and analysis. His determination as to what defined success, failure, acceptance, or rejection was his and only his determination.

As an additional objective and by-product of this process, the author has established a "moderately-rapid" assessment technique to evaluate the technical success and social acceptance of desiccation bathrooms in Central Mexico.

P.5 Data Gathering Methods

To be able to understand the underlying social environment, an understanding of the community history, as related to the sanitation technology, is needed. Below is a summary of the critical points of the fourteen-year chronology of the sanitation program, which have been divided into the following stages and time frames: 1) Antecedents,[23] 2) Planning and Project Methods, 3) Initial Project Implementation (1987–91), 4) Agreement and Village Leader Concurrence (June 1988), 5) Design (1983–88), 6) Construction of Brick Desiccation Bathrooms (1988–93), 7) Initial Use (August 1988), 8) Operation (1–14 years), 9) Maintenance (1988–2002), 10) Modifications (1988–2002), 11) Principal Phase of First Developmental Group Follow-Up (1988 to approximately 1994), 12) Final Project Closure (1997–2000), 13) Community Sanitation Development without strong presence of First Developmental Group (1995–2002) 14) Introduction and Use of Other Sanitation Systems (1996–2002), 15) Abandonment of Toilets (period unknown), and 16) Investigation (2001–2008). Technical or

[23] Prior to the project implementation, indiscriminate defecation was the most predominant sanitation practice, with just a small quantity of families using water-borne toilets, with little or no treatment. Most of those had a ceramic toilet with a pipe discharging to a cesspool—a hole in the ground. One household (family 23) had a waterborne wastewater system with a septic tank and drain field underlying a flowerbed. Although this was a fairly sophisticated treatment system, it did not meet State of Florida Department of Health guidelines.

social factors during any one of the above stages could be responsible for the sustained use or abandonment of the facilities.

5.1 Initial Active Phase of Triangulation (1984–1997)

As part of the three-fold approach of triangulation, the literature review started in 1983. At that point the author began correspondence for four years with various organizations working in Latin America. After four years of literature search and correspondence, the author was well prepared for some site visits. A six-week trip was taken by the author to Mexico where he met with multiple agencies to find an opportunity for the non-profit agency where he was the director to support a project. In 1987, the Mexican Department of Health and the U.S. non-profit agency—Basic Services for the Americas—initiated an agreement to collaborate together to support two communities. The initial project where the participation observation and informant consultation occurred was in a community called Conmexico in January 1988. This project was conducted with the Mexican Health Department. After the contract was completed in July 1988, a health promoter by the name of Armando Galvez continued to collaborate privately with the author, where they worked together on the Sonacala project and various others. The non-profit agency continued with the project in Sonacala and other small pilot projects until approximately 1997. Bi-weekly for 18 months in 1988 and 1989(the health promoter and the author), then later on very sporadic day trips from 1990 to 1997(mostly the health promoter), participant observation and informant consultation was conducted in Sonacala and the other communities by the author. This was considered the active phase of the project.

P.5.2 Development of Field Methods, Materials, and Aids

Physical manual aids such as sample forms (see Appendix W) and methodologies discussed earlier where further developed. In particular the rapid assessment approach was analyzed and incorporated into the methods for this project. Below, modifications for other situations are discussed.

P.5.2.1 Rapid Assessment as Part of Triangulation

The reiterated triangulation procedure is restated below, with specification at what social level (individual versus community) the technique was employed.

1) simple observation (participant observation step at individual and community level);
2) individual interviewing using questionnaires and/or dialogue (participant observation step at individual level) with rapid assessment added;
3) focus groups (combination of participant observation and informant consultation, both at community level);
4) key informant consultation (at individual level).

As can be seen, step two above was expanded to include a method called rapid assessment. Rapid assessment (RA) is a field data collection technique developed by James Beebe (1995) which is explained below.

The RA technique appears to be Bebee's (1995) version of dialogue-type interviewing (participation observation) and perhaps informant consultation, two parts of the triangulation technique. In Bebee's approach, there are three key elements.

1) There must be a multi-disciplinarian investigation team,
2) There must be several members, and
3) The evaluation must be immediate.

This rapid assessment method was shown to be very effective. Two different investigators, with two different disciplines, conducting the same activity provided two perspectives; their immediate analysis prevented loss of information due to memory problems and also allowed minimal note taking by that interviewer, and lastly, enabled one to observe the subjects and their body language while the other conducted the interview. At times the opposite was experimented with—the second person took notes instead of the interviewer to allow the interviewer to focus on the dialogue instead of on his notepad. This should have further relaxed the subject.

P.5.2.2 Moderately-Rapid Assessment

This type of project is a "health" and sanitation project. It takes place in a rural setting, in a low-income community, in a foreign country and culture of both Meztizo and indigenous peoples and is detailed, complex, scientific in nature (engineering), and comprehensive (anthropology). It was a very complex matter that obviously required many years to successfully implement a technology that was well diffused and adopted.[24] As could be seen from the social factor list previously presented, there are numerous influential factors and attributes that have to be considered. To understand, troubleshoot, modify, wait for change, and reassess (as part of a feedback loop) typically takes years for a proper assessment, in this case—14 years of field assessment. Furthermore, after 14 years of the technologies' introduction into Sonacala, its acceptance, innovation, and diffusion is still in its infancy. Accordingly, for this reason, the procedure developed in the associated report was named "moderately-rapid" assessment.

The modification of the name of Bebee's technique is in no way intended to be disrespectful, in fact, on the contrary. On some works, a rapid assessment is all that time, funds, interest, and resources will permit. In those cases the importance and dependence on informant consultation, literature review, and training with HRAF will be even greater. Also, in those cases the work should be cavioted with the condition that a longer term moderately-rapid assessment technique should be performed as a follow-up when resources permit.

P.5.2.3 Solo Rapid Assessment

A further modification of Bebee's approach will be necessary at times, however, in this instance in the direction of possible reduced quality for the sake of quantity. Because of reduced

[24] Literature shows that the typical development cycle is seven years.

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resources and ever increasing community needs, it is believed that more field work will be done with professional support personnel being sent out alone, instead of teams. For this reason, it is important for investigators to have multi-disciplinarian academic background, training, skills, and experience. At the end of the first project in June of 1988, when the contract was terminated with the Mexican Health Department, there was a short period where the author had to continue to go to Sonacala without the local health promoter. This was an uncomfortable time; however, it was overcome by continuing to depend on the local village contact. Also, the approach of participation by invitation only was carried out even more intensely as the author, without his partner and mouthpiece, took an even more passive attitude. No one was approached; the author waited for others to go to the village leader or at times they would come to him directly to solicit support. After the solicitation, the local leader then worked out the details.

The World Bank's WASH project (Camp, Dresser, and McKee, 1983), had a requirement that teams consisted of three individuals: the first person with the technical knowledge (i.e., the sanitation engineer), a second person with social skills (i.e., the rural anthropologist), and a third member with the lingual skills of knowing the local language (Spanish speaker) and of understanding local culture. It was also believed that it was more effective if the project staff was close in origin to the community members. The last two requirements are basically impossible for an outsider to accomplish, so at a minimum a local skilled translator would be needed with an openness and capacity to learn at least a minimum understanding of program philosophy and technology. In summary, one must have the technical and anthropological know-how, know the local culture, and speak the language. This academic work and field experience did prove to be effective in the development of capacity in all three areas—the engineering science approach.

P.5.3 Use of Natural Medicine Question as Part of Interview

The literature review previously presented was a review of historic health beliefs. One of the primary conclusions from it was that there may still exist in Latin America latent beliefs of "hot and cold" concepts and "dryness and moisture" resulting in theories of disease and healing other than the germ theory. The assumption and determination was made that in order to attempt to detect if such sub-conscious beliefs did exist, it was necessary to identify that in the behavioral domain—that is in their behavior. For reasons discussed previously attempting to ascertain this potential belief in the cognitive domain (their thoughts and speech), or in the affective domain (their emotions) was believed not to be effective. Accordingly, a question was incorporated onto the graphical interview tool as to whether the villager used natural medicine techniques. If they did use natural medicine, the basic premise was that it indicated a propensity and openness of the villager to some non-conventional non-scientific beliefs. It was assumed that propensity would influence the villager to be less motivated by the scientific germ-based theory, and more by non-scientific beliefs not based on health, thus lowering his interest in health-based interventions. Natural medicine use and practice could either be more mainstream scientifically based techniques, or more non-conventional beliefs based in religious beliefs or magic performed by local medicine men (curanderos). The head of household for Family 24 did state that he had sought out the assistance of a medicine man, and it appears that the head of household of Family 8 was advised against the use of some type of medication or medical practice. With most other interviewees, the discussions usually never got beyond what type of herb or tea was used and for what physical ailment. There was a lack of comfort of the investigators and insufficient time to explore these issues in a 15- to 45-minute dialogue[25] which was the range of time spent at most households.

5.4 Individual Villager Approval of Investigation

Upon arrival at the home of each community member, an explanation of the investigator's interest was provided and then permission was requested to speak with the family about their toilet. In all cases, permission was verbally granted and in nearly all cases the family's willingness to participate was further confirmed by the investigation team being allowed into the yard, patio, or home for the interview. At the end, two photos were taken. One picture was given to the participants, and the other was signed by the participants. The signed photo was returned to the investigation team for use as documentation of the villager's concurrence and as a record of their name. Only in one instance was it overtly clear that a user was not interested in participating in an interview. She did answer some questions while the investigation team was in the "public walkway" (cobblestone path) and then quickly informed the team that she did not have time to talk any further. She appeared to be angry to a small extent and very dissatisfied with the toilet. The team was respectful of her opinion and time, thanked her for the time she gave them, and then quietly and quickly moved on to the next household.

P.5.5 Assessment of Local Technical Standards and Regulations

Very generally, environmental standards were discussed with the bathroom owners. The feedback of the local investigation team was also obtained.[26] From the literature and this field work, some user standards appear to be: 1) dryness of waste, 2) absence of insects and worms, 3) non-presence of waste (out of sight), and 4) odor. Conventional analytical standards such as fecal coliform and oxygen demand were of course not discovered in this rural area; however, it was observed in their responses that many participants were aware that there are microbial organisms in the waste and their potential threat. After all, is that not the same basic understanding that fecal coliforms are an indicator of potentially pathogenic organisms? They were aware that pathogens existed, without knowing the scientific indicator, fecal coliforms, or what they represented. Although most villagers do not have a long academic training, many are

[25] A local Mexican sociologist who was consulted felt interviews should be limited to 15 to 30 minutes and should be comprised of no more than 4 or 5 questions. This is quite different from one questionnaire produced by the World Bank that had approximately 30 questions on it (Camp, Dresser, McKee, 1983) This is not a criticism of that work. This investigation also had over 15 questions, however, it tried to lessen the impact of them by presenting them graphically.

[26] On a related topic, because it was known that some members had very strong environmental beliefs and strong preference for the desiccation toilet sanitation option, it was agreed by all that the team was not there to promote the toilets, but instead to collect objective information.

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very intelligent and most are “street smart.” Villagers sometimes receive different types of training than formal schooling that have tremendous value also.[27]

Environmental standards were identified in Mexico, particularly urban areas. A student at a university with whom sample analysis was considered explained to the team that they used USEPA protocols for wastewater analysis. His response as to the presence of local regulations was not clear although it appeared there was adoption of some U.S. regulations and standards.

In rural areas, such as Sonacala, there are no environmental regulations, or at least they are not enforced. It is probably reasonable to assume that there is not as much interest by governmental officials as to what happens in rural areas, as opposed to the urban areas where they and their places of business are located. It was known that in one large municipal area within two hours of Sonacala a regulation existed that appeared to ban installation and use of any sanitation technology except for sewer systems. It was also known that indiscriminate defecation or urination was not permitted either.

In Sonacala, there were two instances where information was gained on environmental perspectives. Only one villager appeared to have a strong commitment to environmental protection and knowledge of treatment methods and requirements needed with his septic tank system. It is believed that he could initiate valuable community discussion and improved technical understanding not only with septic tanks, but health and waste treatment as a general topic. The other instance was with the village leader concerning his desire to have a waterborne toilet knowing that it would pollute the canal. He admitted that he knew it would cause pollution, but felt that it was the government’s responsibility to resolve it. At least several were aware that wastewater discharged into a septic tank cesspool contaminates the ground water. As can be seen, there is a level of environmental awareness in the community. Every society must go through steps of “development” and cannot skip any of those steps (Community Resource Group, 1990). Where this community and its members were in that process was respected.

As far as construction requirements, a few families wanted to make minor modifications to the design. That latitude was granted out of respect for local desires, possibility for innovation, and user ownership.

P.5.6 Informational-Gathering Instruments

As mentioned previously, there were various steps and forms that were developed for use in the field. The forms are discussed below and were used in the following order:

a) Introductory Dialogue
b) General Dialogue Questionnaire (see Figure P.6)
c) Operation and Maintenance Questionnaire (see Figure P.7)

P.6 Data Collection

[27] A good example of extensive informal training is that of the aboriginal youth. They go through rigorous training on how to survive in their environment (Edwards, 1999) well into their upper teenage years. Their survival is a testament to the effectiveness of that training.

The field data collection was initiated in October of 2002. Some of the principal factors that influenced the technical success or failure and social acceptance or rejection of the toilets included the following:

1) Insects,
2) Waste handling,
3) Odor,
4) Introduction of additive,
5) Humidity,
6) Inadequate knowledge, and
7) Poor operation

P.6.1 Field Work

At the beginning of the project's field work in October 2002, discussions were held with local Mexican investigators to determine which of the social factors would most probably be present and influential. After each investigator provided his perspective, the final questions were formed, the graphics were developed for the questionnaires, and the forms developed and printed.

The first step in the routine of the field work was the interviews. The individual interviews were conducted first. The dialogue and the observation with community members and informants identified information in the following areas: a) the family's experience with the desiccation bathroom and outside support, b) local beliefs on health, hygiene, and sanitation, and c) a short review of family composition. Very little information was obtained on the daily life cycle of the village.

Upon the arrival of the four investigators at the home of the family, prior to the actual interview, a few introductory questions were asked by one of the investigators. This was the *entry* into the interview, and was important for the first impression and to set the stage for the family visit, interview, inspection, and sampling. The following questions (provided in the full Spanish text below and abbreviated English translation) were asked:

ANTES LA PLATICA ANTES DE ENTRAR A EL JARDIN ("LA ENTRADA") <The Entry>

1) Somos de dos Universidades haciendo una INVESTIGACION tratando de MEJORAR los PROYECTOS DE SANAMIENTO Y SALUD <We are university investigators>
2) Deseamos pedir su CONSENTIMIENTO a platicar sobre el sanamiento (si fueran de acuerdo, firmaran atrás de una foto) < We would like to ask permission to speak to you about your bathroom—if they were in agreement, later in the visit, a picture was taken of them and they signed one of the photos, and they kept the other>
3) ATENCIÓN FAMILIAR <SMALL TALK>
4) Usted tiene un TANQUE DE AGUA? FILTRO DE AGUAS GRISAS? BAÑO? <Do you have a water tank, gray water filter, and/or a bathroom?>

5) Que tipo? Si no, como hacen su NECESSIDADES PRIVADAS?
   <What type? If no bathroom, how do you take care of your private necessities?>
6) Podemos VER EL BAÑO? y sacar MEDIDAS? y INSPECIONARLO?
   <Can we see the bathroom, take measurments, and inspect it?>

Two of the four investigators conducted the interviews, which typically took place inside the home. For the sake of terminology and clarity, two of the investigation team members are being called interviewers and the other two inspectors. These were the two distinct roles that they served.

The first part of the interview consisted of a discussion shown in Figure P.6 below. The items shown in the figure were more points of discussion rather than questions. This part of the interview covered the family's participation, use, belief, investment, cost, and benefits related to the sanitation facility, as well as one question of their healing practices. There were two questions on operation and maintenance. Those two O&M questions are also covered on Figure P.7. They had to be excluded from one of the interview portions.

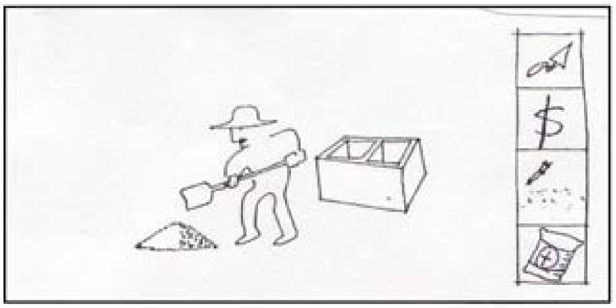
In the second part of the interview, the operation and the maintenance of the toilet was discussed (see Figure P.7). During this same visit to the family, while the two interviewers were inside, the two inspectors stayed outside the home and performed the physical inspection of the desiccation toilet. The inspection form contained a detailed list of all the physical characteristics of the toilet.

After the interview and the inspection were complete, the family was thanked for thier participation and two photos were taken. One of the photos was kept by the family member and one signed and given to the investigators as proof of the family's consent to participate. This was considered a non-threatening approach as opposed to requiring the family member to sign a form. Upon departure, if time and atmosphere permitted, the family member was asked some of the following questions:

The Exit <DUESPUES DE LA PLATICA ("LA SALIDA") >

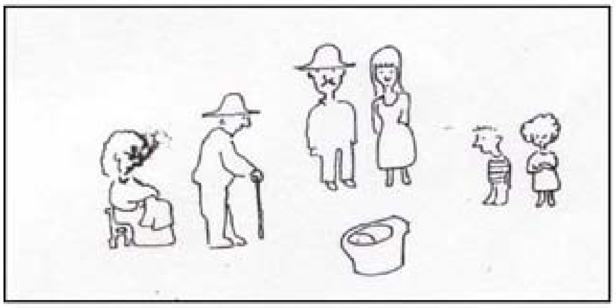
1) Hay algo que no platicamos?
   <Is there anything else that we did not discuss?>
2) Este bano esta aceptable o no aceptable?   PORQUE? Aceptó otro modelo? Cual?
   <Was this bathroom type aceptable to you or did you prefer another type? Why?
3) Podemos SACAR UNA MUESTRA de abono? Cuando?
   <Can we take a sample from the toilet's vault? If so, a time was set for another day>
4) Usted tiene un OPINIÓN LIBRE que desea compartir con nosotros?
   <Do you have another opinion that you would like to share?>

The interviewers thanked the family again, and asked permission to leave ("Con permisso?"). Within minutes of leaving the home, the team found a private place to stop (out of sight of the home), and quickly discussed the results of the interview and inspection. Concurrence on the results was sought.



1 How did the family participate?

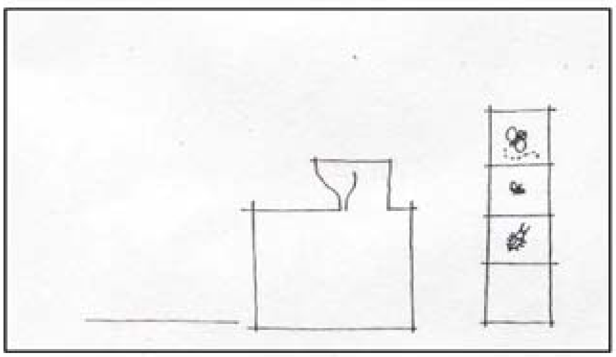
Labor?
Money?
Sand & Gravel?
Cement?



2 Who used the toilet?

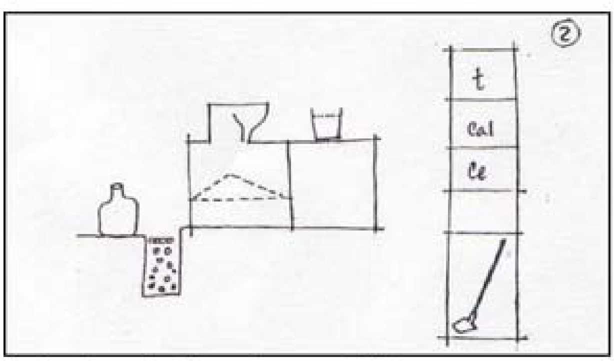
Toddlers (2-4)?	Mother?
Young Children (5-9)?	Father?
Adolescents (10-14)?	Grandparents?
Older Teens (15-19)?	Neighbors?
Eldest Son?	Relatives?
	Visitors?

What did they think about it?



3 Were there any insects / pests?

Flies?
Mosquitos?
Roaches?
Scorpions?
Mice?
Other?



4 What type of additive was used?

Soil?
Lime?
Ash?
Was there a bucket for additive?

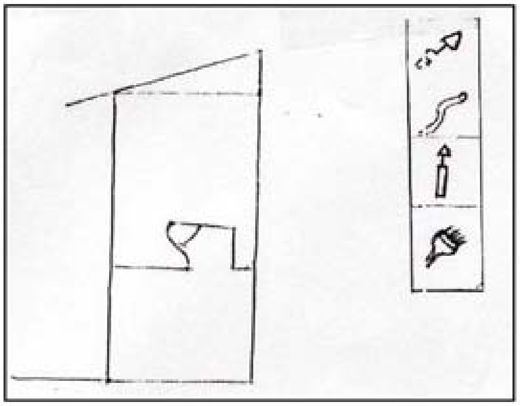
Was the pile leveled? How often?

Where was the urine discharged?

Absorption Pit?
Container for disposal off-site?

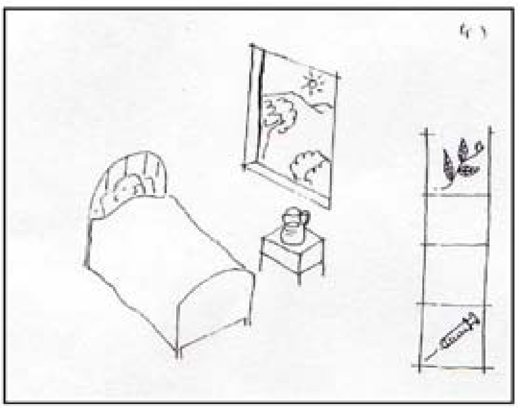
* *Graphics by Cesar Anorve, CITA*

Figure P.6 General Dialogue Questionnaire (Figures by Cesar Anorve; text by author)
(Figure Continued)



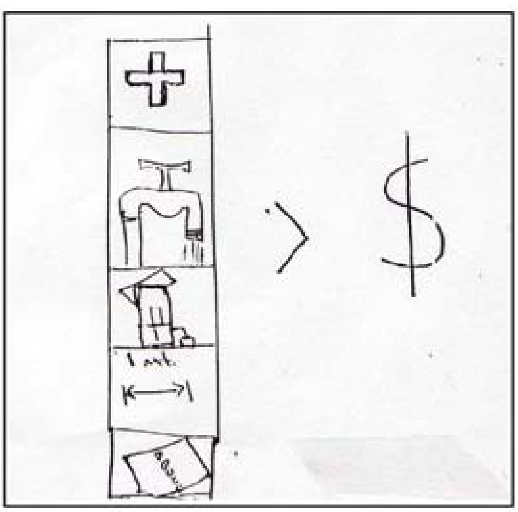
5 **What type of maintenance was needed/done?**

Grouting?
Urine Discharge Hose Repair?
Respiration Pipe Repair?
Painting?
Other?
Toilet-Basin / Seat Replacement?



6 **When you are sick, how do you get well?**

Natural Medicine?
Local Healer?
Religious?
Conventional Medicine - Doctor?



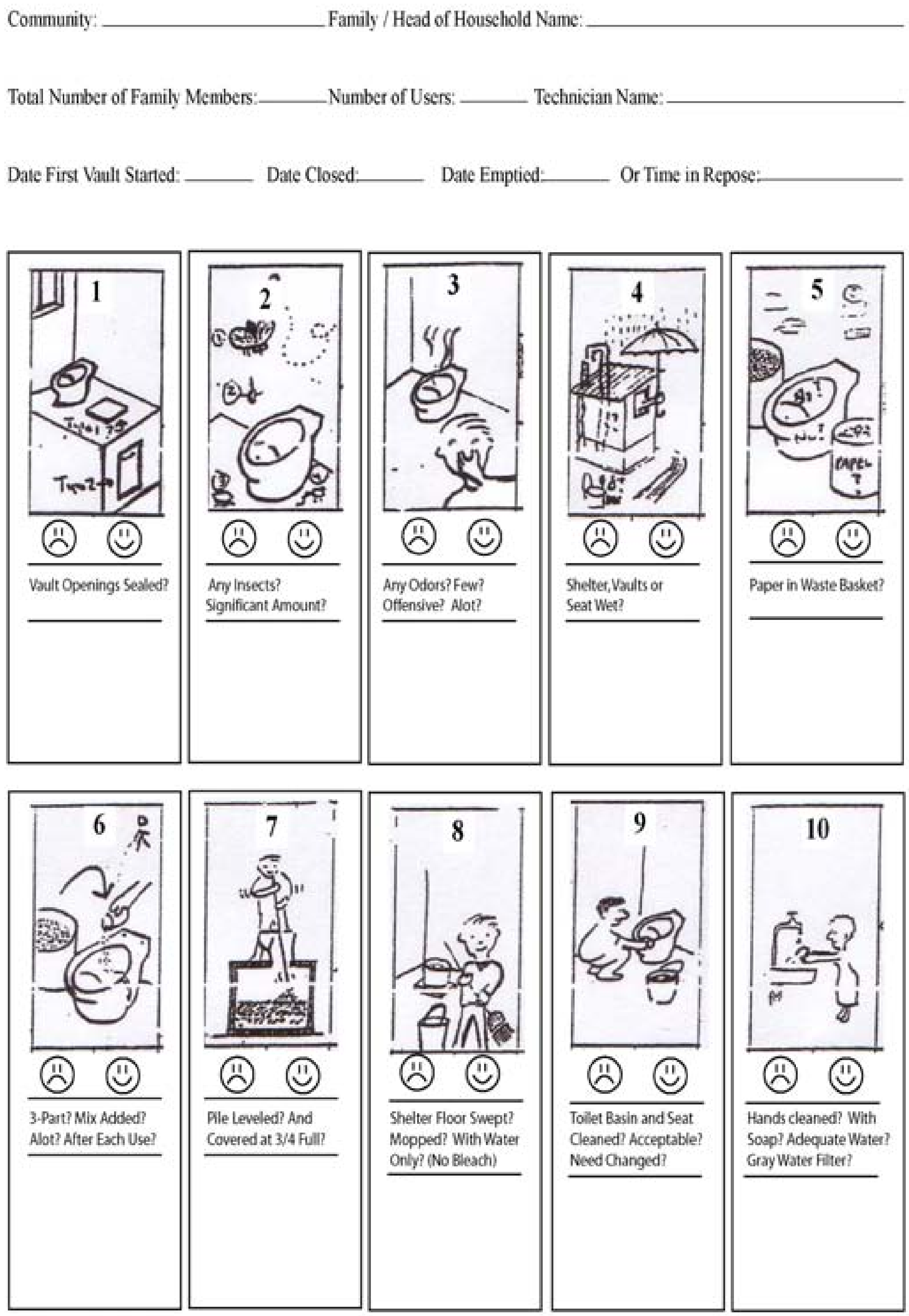
7 **What were the benefits to you?**

Health?
Water Savings?
Convenience?
Proximity?
Compost?

Were the benefits greater than the costs?

Advantages greater than the disadvantages?

Figure P.6 General Dialogue Questionnaire (Figures by Cesar Anorve; text by author)



Community: ____________ Family / Head of Household Name: ____________

Total Number of Family Members: ______ Number of Users: ______ Technician Name: ____________

Date First Vault Started: ______ Date Closed: ______ Date Emptied: ______ Or Time in Repose: ______

1	2	3	4	5
Vault Openings Sealed?	Any Insects? Significant Amount?	Any Odors? Few? Offensive? Alot?	Shelter, Vaults or Seat Wet?	Paper in Waste Basket?
6	7	8	9	10
3-Part? Mix Added? Alot? After Each Use?	Pile Leveled? And Covered at 3/4 Full?	Shelter Floor Swept? Mopped? With Water Only? (No Bleach)	Toilet Basin and Seat Cleaned? Acceptable? Need Changed?	Hands cleaned? With Soap? Adequate Water? Gray Water Filter?

* Graphics by Cesar Anorve (CITA) Centro Innovacion en Tecnologia Alternativa.

Figure P.7 Operation and Maintenance Questionnaire (Original figures by Cesar Anorve; modified by author)

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At the very end of the two-week period, physical waste samples were removed from selected toilets from which permission was obtained. In a couple of instances, it was not possible, or permission was not granted to withdraw samples. The samples were transported to the United States where analyses were performed on them at the Callegari Environmental Center at Louisiana State University.

After all the interviews were conducted, a community meeting was held and an attempt was made to carry it out in the form of a focus group. However, due to dissention among community members and what appeared to be quarreling concerning the toilets, significant dialogue was not possible and this technique was abandoned.

P.6.2 Insects

Insects are not only disease vectors but more from a social standpoint are a nuisance. The approximate number of flies were attempted to be estimated visually to determine the level of nuisance to the user. This was very difficult obviously, but still proved a relative measure. Fly traps could be another method of accomplishing this task however more time consuming and probably unnecessary. It is believed that the insects did decrease acceptance and cause rejection in some cases.

P.6.3 Waste Handling, Use, and Disposal

In the brick and block toilets, the waste is removed from a small trap door on the back of the enclosed vaults (see Figure P.8). It was not as simple and "hands-off" as Figure P.8 depicts. The person removing the waste either has to kneel or lay on the ground to remove the waste using a hoe or a small shovel. In this effort, the most laborious task of all, the individual comes in close proximity to the waste and possibly contact. This process was disagreeable to some and lessened acceptance and possibly even caused rejection. Ghandi apparently chastised his wife because she was unwilling to do her part in the removal of waste from their bucket latrine. This waste handling is one of the two or three most objectionable tasks. It should be understood that the waste removed generally does not have the texture of compost, nor is it raw offensive waste. It is very dry, white in color (due to the lime) and crusty. It does not have the "warm and fuzzy" (rich and organic) feeling of the nature experience of removing rich compost and returning it to the environment. It appears very sterile, especially when a lot of lime is used. Even though there is a lot of lime that has probably completely disinfected the waste, there is usually still a fear of handling the waste. Some of the researchers felt this fear, which was evident by their use of gloves and nose masks—though completely totally unnecessary by another investigator. Once the user has experience doing this task having overcoming the initial fear and possible believed disgust of the task, it can become acceptable. The problem is that some users never get to the point where they are willing to open up the back of the vault and try.

For the fiberglass toilet, the vault is much more accessible and easier to remove. An open bottom vault on the backside of the toilet and a fiberglass bin similar is size and shape as a recycle bin used in some parts of the United States, collects the waste and is removed once filled. The bin is probably approximately 2 feet wide by 4 feet long by 2 feet high, almost half the size of each of the 1 cubic meter (approximately 30 cubic foot) brick (and block) vaults. The only disadvantage to this system is that the detention time is of course significantly shorter, perhaps half, so the waste is not dried out as much so it is more disagreeable visually. Actually the top of the waste is completely fresh excrement, the last introduced just prior to emptying.

The last aspect of waste handling is the leveling that must be done of the waste inside the vault. This is done with a stick or a rod, and involves "knocking down" the conical shaped pile. In that case, the waste on top is raw, so this can be very disagreeable. When people see their own waste it is more acceptable (and some consider interesting) but to see someone else's waste is generally considered disgusting. This task must be done by an appropriate family member that has a higher level of tolerance of a difficult task. See Figure P.9 for examples of the waste and additive: a and b) soil cover, c) lime cover, and d) a bag of quicklime additive. Figure P.10 shows raw waste completely uncovered, a very poor operational practice. All these are examples of very visually unpleasant raw waste (to some), however, when the waste it removed it is very different and very dry. At that point, it really does not look so much like waste, really more like a light white color dirt. A comparison helps to understand the visual aspect of the finished waste. The dried out, crusty waste is similar in appearance to dog excrement that is already desiccated. It's not raw and wet, and it does not smell. Apart from simply disposing of the waste, cleaning the toilet basin, which gets soiled, with excrement, particularly diarrhea, can be unpleasant. A new design of the toilet basin has been made with the rear wall extending and flaring away from the seat preventing the inside back of the basin from becoming soiled.

P.6.4 Odor

One of the most significant problems with the acceptance of the desiccation toilets was odor. Since odor is such an issue, it is valuable to learn more about the actual science of odor and its detection. No laboratory analyses were performed to detect or identify odorous compounds, however, the relative unpleasantness sensed overall by the villager (hedonics) and sensed at the time of the investigation by the local investigation team was noted. An attempt was made by the local investigation team to note whether the bathroom owner appeared to have a strongly negative mental association with the sensed odor. Four levels of odor intensity were considered:

1) It smells very bad! (Huele muy feo!)
2) It smells bad sometimes, or it smells bad. (Huele mal a veces. Huele mal.)
3) The odor is not offensive. (No es ofensiva.)
4) There is no odor! There is very little odor! (No hay olor! Hay muy poco olor!)

Below in Table P.1 is a list of the odorous compounds typically found in wastewater (water matrix) and other ones and their associated odor quality.

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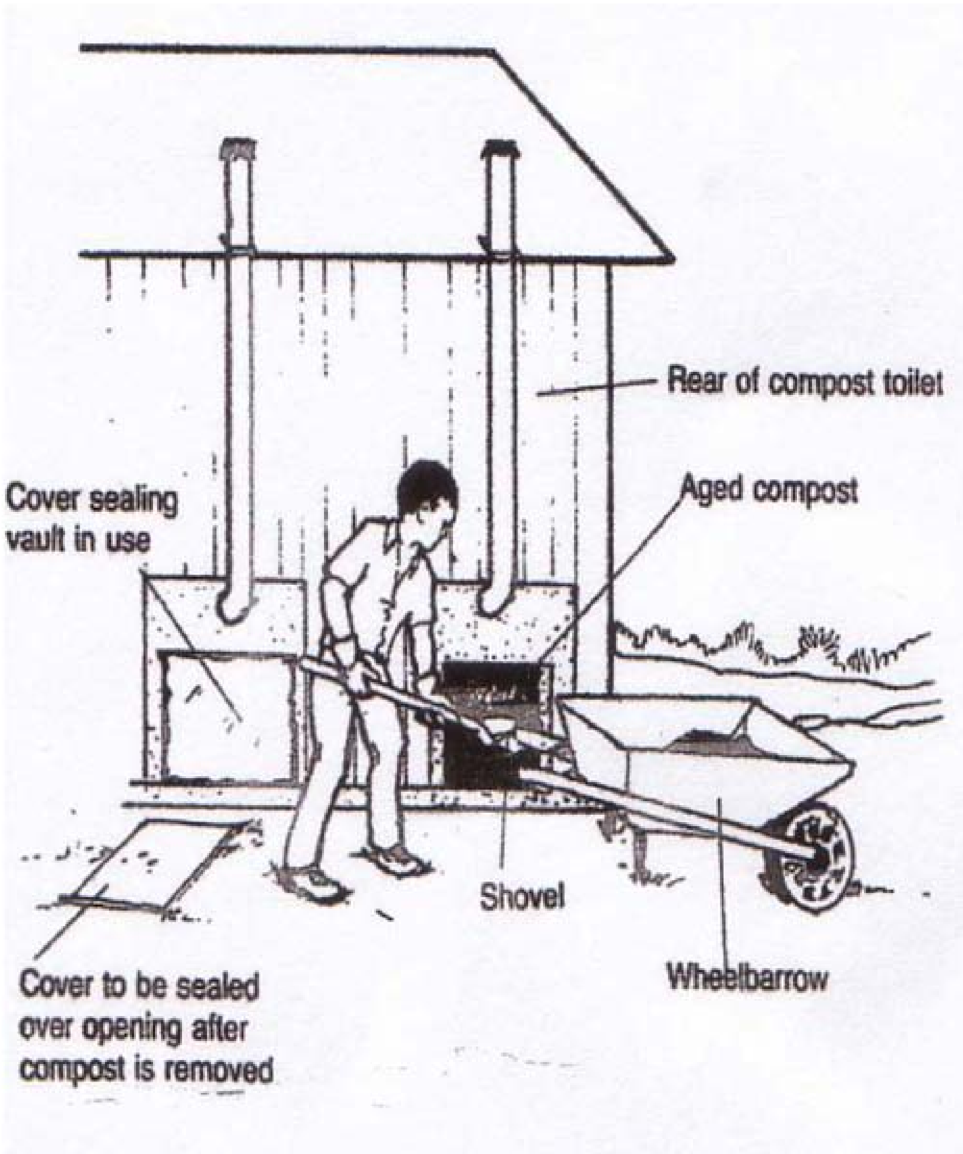

* *Graphics by U.S. Aid Water and Sanitation for Health Project Report*

Figure P.8 Conceptual Illustration of Person Removing Alkaline Desiccated Compost from Enclosed Vault (Double Vault Model Version) (Illustration by WASH Project coordinated by Camp, Dresser, and McKee)

A)

B)

C)

D)

Figure P.9 Examples of Waste Covered with a and b) Soil-Like Additive, c) Lime Cover, and d) Lime Additive (Photographs by Joel Robert)

Figure P.10 Uncovered Waste (Photograph by Armando Galvez)

The only three odors that were suspected were from number 8 fresh fecal matter, number 2, ammonia and number 4, hydrogen sulfide. The fecal matter odor was believed to be detected along with ammonia. The decomposition of human excrement, which contains ammonium, can occur aerobically and can be reduced all the way to nitrogen gas; however, that is not the main mechanism in the desiccation toilet. In aerobic decomposition, adequate oxygen, moisture, pH, and certain microbial organisms must be present. In this desiccation toilet, when adequate amounts of lime are used which creates an alkaline environment (high pH), the ammonium (a solid) is converted to ammonia (a gas). Since both of these nitrogen compounds have odor, until all the ammonium is converted, ammoniacal odors will persist.

Table P.1
Odor Parameters

#	Odorous Compound	Odor Quality	Odor Threshold Detection	ppm Recognition
1	Amines	Fishy	-	-
2	Ammonia	Ammoniacal	17	37
3	Diamines	Decayed flesh	-	-
4	Hydrogen sulfide (anaerobic conditions)	Rotten eggs	<0.00021	0.00047
5	Mercaptans (e.g., methyl and ethyl)	Decayed cabbage	.0005	.001
6	Mercaptans (e.g., butyl and crotyl)	Skunk	-	-
7	Organic sulfides	Rotten cabbage	-	-
8	Skatole	Fecal matter	0.001	0.019

To determine if hydrogen sulfide could have been present requires an understanding of the process. In the anaerobic degradation process of proteins, when sulfide bacteria are present, the commonly known odorous hydrogen sulfide compound is produced. Sulfate ion occurs naturally in wastewater and is required in the synthesis of proteins and is released in their degradation. Sulfate is reduced biologically under anaerobic conditions to sulfide, which in turn can combine with hydrogen to form hydrogen sulfide. Since the alkaline decomposition in the desiccation process is really not an anaerobic process, and most often not a biological process, the possibility of hydrogen sulfide odors was small. If there is a hydrogen sulfide smell, this probably is indicative of the waste pile being compacted under its own weight due to insufficient additive being introduced and the pile remaining wet. At this point the pile could become anaerobic and produce hydrogen sulfide.

Finally, in reference to odor, there are four factors that must be considered for the complete characterization of an odor. They are 1) character, 2) detectability, 3) hedonics, and 4) intensity. To date, detectability is the only factor that has been used in the development of statutory regulations for nuisance odors. Although measurement of odor is outside the scope of this work, the following three items would be beneficial to address:

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1) A knowledge of the processes that produce particular odorous products, and byproducts,
2) Identification of means to abate (reduce or eliminate) the odor, and
3) The names of the commonly-known items that produce a similar smell.

The last one could be helpful in communications with villagers to identify which processes are occurring in the bathrooms and any needed remedial measures. Identification of odors could help villagers understand the process occurring and use that knowledge as a learning experience and a cue to take remedial measures to restore the toilet to its proper operation. This should help villagers to not blame the toilet and prevent the reduction of the prestige of the toilet and increased acceptance.

P.6.5 Location

The first step in construction is deciding on a location for the bathroom. Location is not an easy choice to make properly. Some users prefer to be away from the home. According to one investigator "one man . . . said that he just did not feel comfortable responding to nature in the home. To him, this was an act that could not be satisfactorily carried on within the confines of a house because it was rated as something unclean and he felt compelled to get away from living quarters to carry out such functions (Elmendorf and Buckles, 1980). Although the desiccation toilet is not generally located inside the home, the application here is that a person with this attitude would not want his toilet close to the home. On the other hand, other users prefer for their toilet to be closer to the house, such as Family 7. They feared having to wander out at night and possibly be bitten by a scorpion or trip and fall on a rock. Others want the toilet to be located close by to avoid getting wet by rain. Privacy issues from neighbors and pedestrians also exist.

The fiberglass toilet provides the greatest flexibility for determining a site that is most suitable. This is because it is portable. If the initial site selected becomes unsatisfactory, it can be moved to another site. Even if the fiberglass model is not the model desired, if the user can temporarily tolerate its shortcomings these will provide a "location" benefit. Also, it allows the community to get the program started more quickly and increase coverage by getting more users started without less upfront investment. The existing inventory of fiberglass models could be used when current users deciding to switch models could make them available. The new user could exchange his labor to help the existing user construction his new toilet in exchange for the provision of the fiberglass toilet owned by the existing user.

6.6 Fear and Disgust of Waste

As mentioned previously, some men have a fear of their waste. Of all the social factors and their hidden nature – the one that definitely comes to the surface of the consciousness of the individual is that fear. In a sense, it can be thought of that there are few social factors — that is ones that are obvious and overt—however, that fear is one of them. There may be a few more, such as disgust. Some of these are most evident and visible in the people's actions, or avoidance of actions, in the operation and maintenance of the desiccation toilet. The most prominent one *is* the fear and disgust of the waste handling. The principal O&M tasks that are the most objectionable are: a) the leveling of the waste, b) the maintenance of the urinal discharge hose that sometimes becomes disconnected or clogged, and requires physical handling inside the vault, or total replacement, c) the sight and smell of the waste in the process of the addition of additive, and d) the removal of the waste from the door on the back of the vault, at disposal time when the vault is full. This operation and maintenance activity, discussed above, deserves special attention. In some cultures and individuals, there is both a fear of their waste, based in the physical scientific phenomena that the individual believes or knows that there are unclean substances in the waste that can cause illness and disease.

In Muslim societies, there is an objection to waste handling because of religious beliefs that the waste is unclean and there are prohibitions against certain types of handling that are based in religious doctrines (Camp, Dresser, and McKee, 1983). In Sonacala no such religious objection was observed, nor was it looked for in the interviews or in the informant consultation. The other social factor is the individual's disgust of the sight, smell and nature of human waste. Because of these phenomena, that are both physical phenomena and also have a sociological component, the individual wants to put distance between themselves and their waste. This is the well known concepts of "out of sight, out of mind", "not over there", and "not in my backyard". For some individuals, this is the case with the sight and smell or a person's own waste, and even worse and more intensively with other people's waste. For other individuals, it is believed that people have a curiosity in relation to their *own* waste in the toilet bowl, but entering a bathroom and seeing someone else's waste is usually considered disgusting and objectionable by almost anyone, except perhaps parents of small children. In the desiccation toilet, the waste that is in the vault is not only one's own, but all the users that came before. It is not a pleasant sight (see Figure P.9), especially when the waste does not have sufficient cover (the additive of lime, ash, and/or soil) from the users before. For this reason, it appears that the toilets are disagreeable and even rejected by some. In a conventional toilet one flushes their waste away. There is a significant feeling of comfort when one pushes the lever down on the toilet, and woosh the waste is taken away—"out of sight, out of mind," the disgust is gone in 15 seconds. No sociological objection to the waterborne toilets exist, and a strong preference for it, for this reason.

P.6.6.1 Summary of Operation and Maintenance Tasks

In summary, the O&M tasks are:

1) Leveling
2) Maintenance of Discharge Hose
3) Addition of additive
4) Removal and Disposal of Waste

P.7 Information Review

Upon return to the United States and after reviewing all families and bathrooms, the forms were modified. They were also coded so that the information on the field forms could be

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transferred easily to the intermediate and final dissertation and moderately-rapid assessment (MRA) tool forms. The style of these forms and the MRA tool developed could parallel the format used by the sanitary sewer evaluation survey investigations and rehabilitation programs in the United States. Field data could be converted through a MRA tool to its final format for its use in the assessment of the success and acceptance of the technology and its recommended O&M practices and rehabilitation**.** Over a several year period (part time), the social factors were analyzed various times, always resulting in *stalling out.* The analysis of the qualitative information was difficult and actually impossible in this case, without some type of assistance. That assistance, or tool, to the analyzer (the author in this case) was the simply quantification with a system of +5 to 0 to -5. With the numerically-rated *quantified* factors, it was then easy to go forward and decide acceptance or rejection, and success or failure (see Appendix X).

P.7.1 Temporal Nature of Acceptance

Acceptance and rejection are not always clear. This is partially because the definition of these concepts is not always understood and its status fluctuates over time. Also, the user's and the investigator's perspectives are different. There are degrees of acceptance and rejection. For example, the discontinued use after a short operating period could be considered a rejection or could be a limited acceptance. Discontinued use after several years could be considered a limited success as a permanent technology, but a complete success as an intermittent measure. There is a need to clarify between the lines of acceptance and rejection. A list, or menu, of the social factors, indicators, and parameters is needed as an explanation of their impact and inter-relatedness.

P.7.2 Acceptance and Use versus Rejection and Abandonment

The influence of social factors on use or abandonment was analyzed with the limited data set of the 24 families visited, who were mostly still using their toilets. Very few households who actually abandoned facilities were interviewed. This was because one of the main types of homes targeted were ones where the toilets were at the end of the treatment period that could be sampled. However, there was enough commentary from other individuals with high levels of dissatisfaction to determine the rejection and failure points. Also, the reasons that the households had discontinued the toilet's use or rejected it were clear and informative. Lastly, some homes where toilets had been abandoned and where households were dissatisfied were included also.

P.7.3 Influential Social Factors and Social Indicators of Acceptance or Rejection

Some of the obvious participatory indicators of acceptance of technologies are actual use, length of use, percentage of use by the entire household, use of the waste (as compost), positive declarations by users (lip service), and proper operational and maintenance habits. On the other hand, rejection can be indicated by some obvious items such as non-participation in a sanitation program, lack of initiation of use of constructed toilet, abandonment of use after a short initial period, partial use or begrudging acceptance and use, negative declarations by families (criticism), continued use of water-borne sanitation systems and values, and inadequate operational and maintenance habits.

Some of the major factors contributing to acceptance or rejection and success or failure are shown in Table P.2 below. Those factors were determined from the review of the dialogue with the 24 families, the physical inspection, and the sampling. Graphs of acceptance or rejection and success or failure for each family have been developed and are useful in their analysis. Determination as to whether a factor is technical or social in nature was sometimes unclear. Regardless, this analysis and determination is just a matter of classification, and has little practical importance. It was considered that technical factors are ones directly influenced by the design, the toilet features, and perhaps the treatment process. Factors that were considered both technically and socially related were those pertaining to the O&M of the toilets. Factors considered strictly socially related were those based on conceptual constructs, emotions of user, environmental attitudes, and health and sanitation beliefs.

The social and technical factors were categorized as either being "indicators" of acceptance (or rejection) of the desiccation bathroom or "factors" influencing its acceptance (or rejection). A difference between a social "factor" and an acceptance "indicator" must be distinguished. The influential social factor (ISF) is the parameter that actually affected the acceptance. The social acceptance indicator (SIA) is the parameter that was a signal, or an indication, that the technology was accepted by the user. For example, unwillingness to handle the waste in the changing of the vaults was a social indicator of rejection, whereas the actual ISF was the individuals fear or disgust in handling his waste. The classification of the parameters as either an ISF and/or SIA or social indicator of rejection (SIR) is shown also in the table. As factors of acceptance or rejection, these parameters become necessary requirements of the user or the technology. Note also that some of the parameters are actual end goals of the project, that is, use and absence of insects.

P.7.4 Pink and Gray Elephants as Social Factors

The right hand column in the above Table P.2 shows that various factors were actually not identified in the interviews or inspections at the households. This was a significant finding. Ever since 1983 when the author published his first work on the technical factors of on-site sanitation technology, he has been in search of those social factors. In the report, he made a strong note that the social factors must be indentified and incorporated. The search that began 25 years ago has come to an end. In retrospect, it is evident now that there were few "pure" social factors that were overtly identifiable and volunteered by the subjects as their reason for rejection of a toilet. Some pink elephants were being chased.

Pink elephants are considered hallucinations that are imagined and seen while in a drunken state. In this work, some of the imagined concepts were social factors which could be called *voodoo* factors. By this term, it is implied that the type of social factors often sought after by investigators are those types that are very interesting and intriguing ones—the magical type or cultural type. These are often the fascinating type shown on television programs that include a lot of drama and perhaps exaggeration to entice the viewer.

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TABLE P.2

Influential Social Factors and Social Indicators of Acceptance/Rejection

Factor or Indicator	Classification	Factor Type	Family where Encountered**
Odor (olfactory unpleasantness)	ISF	T,S	
Insects	ISF, Goal	T,S	
Waste Handling Objections (based on fear or disgust of waste)	SIR	T,S	
Desire to put distance between man and his waste (Fear & hygienic values)	ISF	S	A
Effort* Required Manageable or undesired	ISF	S	#1
Privacy	ISF		
Convenience	ISF	S	
Comfort	ISF	S	
Health	ISF		
Personal Hygiene	ISF		
Cleanliness of Toilet and Shelter	ISF, SIA, SIR		
Initiation of Construction and Use	SIA		
Length of Use	(SIA), Goal	T	Many
Age	(SIA)	T	4, 8, 22, 24
Completion of Single or Multiple Cycles	(SIA), Goal	T	4, 8, 22, 24
Use of waste as compost or additive	SIA	T	24
Technology Innovation	(ISF and SIA)	T	Family w/Fish
User Financial and Time Investment	(SIA and ISF)	S	2
User Testimonies	(SIA)	S	Various
Key Words/Body Language	(SIA)	S	Various
Personality Type	(ISF)	S	A
Ownership Attitude/Commitment	(ISF and SIA)	S	
Valuation by Owner (w/ B/C analysis)	(ISF)	S	
Investigator Observations	(SIA)	S	
Availability of Water	(ISF)	T	11, 22, 24
Ability to Excavate Pits or Tanks	(ITF)***	T	11
Cost	ITF	T	8
Others			

*An effort to make additive and remove waste.

** An “A” signifies that this parameter was not actually directly overtly identified; it was inferred by the investigators.
*** ITF denotes influential technical factor.

Some examples of these overtly interesting social factors are 1) the Islamic hygiene prohibitions related to the use of their left and right hands in respect to anal-cleansing and food handling, 2) local healers’ use of natural medicines, 3) local medicine men using magic to dispel evil spirits by, for example, removing a heated pebble containing the evil spirit from a sick person, 4) Use of separate sanitation facilities for men and women because of fear that women could become pregnant if they use the same latrine as men, and 5) belief that children’s feces do not contain harmful pathogens.

All the above factors are real, intellectually stimulating, and interesting. In reality many, if not the majority, of the factors are very common social factors, many of which have a technological component. Some examples of these simple, combined social/technological factors are those previously mentioned ones of odor, waste visibility, insects, perceived cleanliness, and cost. Accordingly, sometimes the elephant is pink—interesting and elusive; sometimes it is gray—simple and overt; and last of all, sometimes it does not exist at all.

Sometimes the social factors are concerns put forth by the outside developmental group personnel based off their legitimate concern and planning of their philosophical speculations and sometime based on non-applicable experiences, beliefs, and attitudes that they have as a result of experiences elsewhere with other communities and projects. In that case, experience is not a good thing when it results in misapplication of preconceived notions.

Instead of making these assumptions, communities that take the lead to plan and design their own programs and implement resulting pilot projects overcome this problem and need for extensive pre-project analysis and social factor determination. Finally, this allows the community to plan for the social factors the best they can and then responsibility and deal with the factors and issues when and if they come up. Although the social factors are very difficult for the outsider to identify and grasp, it is believed that although the community may struggle with this also, the factors and issues are better defined in their heads and in their plans for their projects. This does not negate the helpful objective role that outside experts and developmental organizations serve. As entities on the outside looking in, they see things that the community may not. Instead, this basic belief that the community usually knows best only places the outside group second in line behind the community in defining and dealing with social factors.

The factors do exist, but many are concealed in the minds of the people who were unwilling[28] or unable, to express those influences. Also, as discussed previously, a decision was

[28] A community would not divulge exactly what their plan was to raise funds.. It turns out it was the building of a dance hall. They would not divulge the idea because of concern another community would steal the idea.

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made by the investigation team to not probe for those factors except for the natural medicine-alternative health theory concept. Many of the factors were technical phenomena, which had a sociological component. The investigator must be comfortable with uncertainty. In the analysis of human beings, one cannot be so decisive (Richardson, 2008). For every force placed on a human being, unlike in engineering, there is not an equal and opposite reaction (Glennon, 1981). Participants in a program cannot be chosen so rigidly based upon predetermined factors and estimations of their potential to be successful users (Esteva, 1988). Accordingly all or even many of the factors cannot be identified in the programming planning, design, incorporation of participants, and evaluation. It must be realized that it is from the informal benefit-cost analysis that villagers perform in their heads and from the pilot projects is where the factors play out, value is accessed and final decisions are made.

P.7.5 Benefit-Cost Analysis

The villager establishes what the things of value are in his life through a benefit-cost (B/C) analysis and as a result establishes "value" and whether the desiccation toilet has enough value to him for the cost he will incur. Is it worth it (vale la pena)?

Direct and indirect benefits and costs are perceived and experienced by the users. Dr. Daniel Okum (1987) of North Carolina University outlined various benefits, not directly quantifiable, besides health such as convenience, quality of life, improved education, increased productivity, comfort, et cetera. Different investigators, such as Camp, Dresser, and McKee (1983), have pointed out the need to do benefit- cost analysis, which is the way that villagers (and probably everyone) make their decisions. Just as engineering decisions are based upon a cost-benefit analysis, as mentioned, potential latrine builders also perform a conscious or subconscious cost-benefit analysis before making a decision to build. However, at the individual level, the categories of costs and benefits are more than just monetary. They include physical, social, physiological, possibly religious, and other categories. A positive decision results if the decision-maker perceives that the overall benefits in all categories exceed the total costs. Although benefits were not quantified, it is very reasonable to assume fiberglass toilet costs were higher than benefits therefore resulting in a B/C ratio of less than one. Some governmental agencies considered that B/C ratios must be greater than 10.0 to be awarded funding. As for if the B/C ratio for the brick and block toilets was attractive, it is much less clear. Perhaps the toilets that had averaged 3.0 scores or more had acceptable B/C ratios. This would especially be the case if the toilets had three years of service and one successful cycle of use, switching of vaults, and reuse or proper disposal of desiccated material.

One question on the General Dialogue Questionnaire (see Appendix T) did ask whether the interviewee felt the benefits were greater than the cost. Most responses indicated that the question was not understood as proposed. The question was reduced by the villagers to a simpler question that really summed things up best. The question was "Is it worth it?" (Vale la pena?). "Yes or no." No list of benefits was volunteered by the investigation team—only upon eventually listing them out was the interviewee able to respond. Camp, Dresser, and McKee (1983) pointed out that villagers must choose between different projects as to where to invest their time and money, just like any community. For example, in the United States, a homeowner's association allocating funds. So, bottom line, in the villagers' evolution of social acceptance of the toilets, it may come down to simply whether the pluses (advantages) outweigh the minuses (the disadvantages) of its construction use, operation, and maintenance.

Individuals everywhere are different. In Sonacala, the villagers have their own way of analyzing benefits and cost. In the final analysis it is unknown how the villagers perform their decision making. An assessment tool was developed to assist villagers in that decision making and provision of that information to the project technician in the analysis of results. That tool will help the villager and technician to communicate that information. On the other hand, as straightforward as it may seem, it still has its limits. It is an attempt to create a tool that appears logical to the technician, but not necessarily logical to the villager.

It is a requirement of one investigator that his students at the end of the reports state the "bottom line"—what is the basic conclusion. The bottom line in reference to the villager's decision making process is that it could come down to simply the asking and answering of the question: Is it worth it? Yes or no. The answer would be known, but not necessarily the reasoning. Furthermore, follow-up visits to the home to verify that the toilet is being used, and being operated and maintained properly, is the ultimate confirmation of the decision and resulting acceptance or rejection of the toilet. That feedback gained must be incorporated into the sanitation activities at the home and in the village.

P.7.6 Feedback

Although there are plenty of influential social factors that are intangible and uncontrollable, there is one that is controllable—continual feedback. Well-thought programs, with a good effort at incorporating the factors in Appendices Q through U and Table P.2, which incorporate continual feedback, can be successful. The critical aspect of a system is one where continual feedback from the users based on learning from their experiences is employed by adapting the program to this behavioral (more dependable) information so that the project can respond to actual community-felt needs. Since opinions and willingness of users to participate can change quickly, particularly with new unproven technology (at least unproven to them), a moderately rapid assessment technique is needed to improve acceptance and use by the users and prevent damage to the technology's reputation and prestige in the broader community.

P.7.7 Influence of Time and Changing Demographics

Technological development and diffusion is even longer than the seven year developmental cycle discussed earlier. The development of this technology within and outside the community will have an effect on the future status, acceptance, and success of it. Also, changing demographics—that is, new and different users (age, gender, and geographic origin)—had and will continue to have a big influence also. Younger users were seen to less accept the rustic-appearing and less modern technology, young children had difficulty using it properly, outsiders were more critical of it and more economically well-to-do residents did not have the economic necessity for it. On the other hand, the elderly had more of an ability to see its benefits and more willingness to overlook its deficiencies. Women, who were homebound, and had a greater need for the toilet, accepted it more. Men, being away from home, had less need for it after they became exposed to, and accustomed to, using pour-flush or even pressurized waterborne toilets in public places.

The demographics of this community had changed significantly over the time span of the technologies' presence in the village. Previously there were mostly long-term inhabitants in the village. More recently there had been an influx from Mexico City, who brought different values with them. The values of these city dwellers from one of the biggest metropolises in the world, who have come to the country, are believed to have changed the acceptability and scrutiny of the technology. There probably exists more criticism and less tolerance of poorly maintained toilets and less community cohesion. These individuals, frustrated with the overwhelming pollution of Mexico City, have "come to the country" to escape the big city's problems and did not want to be exposed to what they perceived as a technology that is contaminating their new environment and is archaic, especially from their perspective of having lived in the capital with all its modernism. Also, the concept of "flushing waste away" is very predominant in Mexico, especially in the cities, in that once you push the lever, the waste is discharged, goes downstream, is "out of sight and out of mind," and more importantly, out of the community and their backyard. Not only these new inhabitants, but it appears plenty of long-standing households, rightly or not, perceived the technology as rustic and primitive, and because of modernism and "their fear of their waste, they preferred the option of putting distance between themselves and their waste" (Robert, 1988).

When the developmental group was in the community in the late 1980s and 1990s, there appeared, at least on the surface, a warmer feeling, more acceptance, more respect for individual desires and choices. Requests for toilets were coming in, new construction was occurring, and the toilets were "still fresh and clean"—the technology and the project were on the upswing. Even though the effort was never really a "community project" it appeared to have an implicit acceptance. By the mid- to later 1990s, the honeymoon stage of the project was over. As toilets matured and aesthetics lessened, more problems arose with less outside help. Their acceptance dropped, problems arose, and less developmental staff was able to help trouble-shoot them and defend the technology therefore toilets did start to fail. The project was on the downfall and the technologies' reputation had been damaged.

P.7.8 Percentage Coverage of the Community

The three different technologies were all introduced at different times. Twenty to 30 brick toilets were introduced in the late 1980s by the developmental group. Not long thereafter, the local municipality paid for the construction of more brick toilets—perhaps another 20. The non-profit supported a few more sporadically, and innovations were being made over time, especially with the toilet basin and seat. Originally, there were approximately 60 families in the community, then that number increased to 90 to 100 not long thereafter. Coverage was fluctuating roughly between 30 and 50 percent. Later, approximately 20 to 30 of the fiberglass versions were brought in and completely installed by the private business. Perhaps even the location in the yard was determined by the outside business staff without regard to personal preferences. This also excluded the family's contribution of their labor. Another 20 to 40 block toilets were supported by an environmental branch of the state and there were reports heard from them about location criteria dictating minimum set-back distances from the home. This mis-information implied potential contamination from the desiccation toilet, thus decreasing the perspective in regard to its hygienic characteristic. With the migration of individuals into the community, most assumed not to participate, the coverage with desiccation toilets then went down. The number of households at the time of the investigation was well over 100, perhaps upward of 150. Coverage then would be at 5 to 20 percent. The level of the community with sanitation service is one method to gauge the success of projects. Accordingly, from a coverage standpoint, the project was inadequate and could even be considered a failure.

P.7.9 The New Sanitation Question

As far as more positive perspectives, instead of a failure, the results can be considered a limited success. There were very positive results at individual households and new toilets continue to be built. As the water shortage gets more critical, acceptance and coverage could well increase. It appears now the question on some community members mind is not whether the technology works, but instead which one of the three desiccation toilets works better. Also, there are probably less households with the practice of indiscriminate defecation in the field. This traditional habit was more possible when community population density was less. Now, with more people moving in and the neighbors next door being more critical, indiscriminate defecation is less feasible, not only from "peer pressure" but also from the standpoint that the individual desire for privacy with this act is less possible with the increased population. Indiscriminate defecation is not only, not acceptable to the neighbors, but neither is it to the individual. A more-private option was needed.

Availability of water, actual physical ability to construct, cost, and privacy will be dominating factors forcing the ultimate decision. Continuance of status quo is no longer an option—change is almost a certainty. With all these factors in mind, households will have to choose between the water closet and the desiccation vault.

P.7.10 Local Beliefs and Practices in regards to Health and Curing

Some of the significant conclusions that can be derived from the literature above were that 1) local natural medicine clinics and practitioners used herbs as a healing technique which was a curing practice not only based in science, but also in the humoral system; villagers, with less access to medicine relied more on cheaper herbs and believed they could solve any ailment, 2) the concepts of an attack of heat or excess heat, or cold, could be beliefs that villagers had that

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would to some extent negate their capacity to understand that the causes of their illnesses are due to microbial infections as opposed to these mechanisms, 3) herbs were used extensively in the community for illnesses and could be an indicator that humoral beliefs do persist in the community, and subconsciously, 4) no evidence of emotionally-derived beliefs on causes of illness were observed, and 5) scientific beliefs of the "germ theory of health" were widespread if not complete with all the villagers.

P.7.11 All Other

As can be seen the issues related to on-site sanitation are varied and complex. Care should be exercised in over-simplifying. Further information is provided in Appendices Q, W, X, Y and Z.

P.8 Technical Results

1) Odors and insects (i.e., flies) were the most frequently reported problems. There was one report of great concern that there was a massive fly infestation that caused many to reject the toilets where they occurred and decreased overall prestige and reputation of the toilet.
2) The desiccation toilet was perceived by some to be non-hygienic.
3) When not properly operated and maintained, the desiccation toilet did have significant odor, insects, aesthetic, and waste handling problems, which resulted in toilets that failed and that were rejected.
4) The social acceptance rate by individual households of the toilets appeared low. There were commentaries received that large numbers of desiccation toilets were rejected. Those households were not visited nor were their technical success or failure known.
5) The brick and possibly the block toilet types were tremendously overdesigned with detention times of 3 to 6 years, unnecessarily longer than the required one year. They were the preferred types as opposed to the fiberglass toilets, which had many reports of uncomfortably high temperatures inside the shelter and strong odors. The fiberglass toilets' advantages were its portability and removable vaults, which are easier from the standpoint of waste removal and management.
6) The lime desiccation process in the toilet, in which raising the pH with quicklime and lowering the water content are the principal treatment mechanisms, is accomplished principally by addition of a mix of lime, soil, and sometimes ash, and not allowing introduction of any liquids to the vault, including urine. The proportion of the three components of the mix is not as important as the generous use of it.
7) Disease prevention was accomplished as indicated by low fecal coliform counts and environmental protection standards met, evidenced by low remaining oxygen demand in the waste. Nitrogen, phosphorus, and potassium levels were so low that the waste had little compost value. Less detention time could provide improved agricultural value for use on fodder crops, ornamental plants, or "tall" plants. Heavy metals were not a concern. In some analyses, alkalinity, not pH, was the limiting factor for disposal and/or application of the waste, especially where the soils are already alkaline. Most importantly, the toilet did not waste water nor did it require it for its functioning.

8) The most significant operation and maintenance results were that large quantities of high pH additive should be required to be prepared in advance for regular use and when problems arise. Also, introduction of urine, bleach, water, or any other liquid to the vault is prohibited. Care to ensure that bleach (sometimes used on the floor for cleaning) does not come in contact with quicklime since it is reported in the literature that a deadly gas is produced.
9) As far as technical support, technical assistance and follow up are required at a minimum at the time of the switching from the first to the second vault (6 to 12 month mark) and emptying of first vault (12 to 24 month mark). Feedback from a qualified team and a method to provide that feedback to users is needed to assist in converting user experiences and concerns to valuable knowledge, know-how, and technological innovation.

P.9 Main Anthropological Results

1) The social factors identified *were* influential in the acceptance and rejection of the technology (see Table P.2).
2) Only faint indigenous health values, related to natural medicine, were potentially perceived in the village.
3) Although the germ theory of science is believed to predominate analytical perceptions of the waste, illness, and healing; villagers do have different logic, thus making ineffective some aspects of health-based initiatives.
4) Villagers use benefit/cost analysis to assess value and make their decisions.
5) Social acceptance and technology design and implementation all change over time.
6) There were various social factors that *could not* be identified, thus requiring the need for a system of continuous feedback employed for technology and project modification, and pilot projects to allow the social factors to play out—to let time tell its story.
7) Continued conjecture of influential social factors and social indicators of success should not be made nor should invention of more pink elephants.
8) Uncertainty is acceptable.

P.10 Overall Anthropological Results

The assessment termed "*moderately*-rapid assessment" conducted with a small, rural Mexican community using the field investigative technique of triangulation, combined with a tool developed by James Beebe (1995) called rapid assessment was successfully employed. Triangulation used as an anthropological ethnographic approach, was a constructive tool that did involve and gain the following: 1) participant observation, that is the investigator being in the community for a long period to observe the communities' behavior, participate in their daily activities, and view the world through their viewpoint, 2) review of what others have done on the subject of the investigation, and 3) informant consultation of local experts. In Bebee's rapid assessment approach, the required tasks were to a) have a multi-disciplinary team, b) to have

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more than one investigator, and c) to make an immediate assessment were all accomplished to a reasonable degree. The triangulation approach was conducted over a 20-year period while the rapid assessment was done in approximately two weeks. Combining the strengths and weaknesses of both methods it was determined that only a *moderately* rapid assessment at the best could be done, in this case a moderate time frame of 20 years, considering the investigators were not in the community full-time and the 14 years spent was not enough. More practically, in the case of desiccation toilets, a moderate period will be considered a minimum of 13 to 25 months—1 month for construction and 12 to 24 months to observe the operation and maintenance of the toilet and to analyze the waste at the end of the second vault's closure, after 6 to 12 months of treatment in the second vault, and 6 to 12 months of previous treatment in the first vault. Assisting the users through this critical waste handling, use and/or disposal task was critical and helpful for cases as indicated by successes at those families. Observations were made over the 14-year period of peculiar activities that were not possible to see in the two-week period of the rapid assessment.

Literature showed that a developmental project is typically a seven year cycle, which in this case, the non-profit intervening organization fell short from the standpoint of close-enough contact with the community. The decreased intensity of follow-up from this non-profit group in years 5 through 7 was believed to be a factor in the eventual rejection of approximately 80 percent of the facilities. During the 5- to 10-year period when the non-profit group had already started to withdraw, there were new competing technologies (the block and fiberglass versions of the same concept), promotional propaganda, and philosophies. Also, these played a role and were influential. The governmental and also the private, for profit business, and the pre-existing influence of the *modern* sanitation conventional toilets entered the picture. All three started to challenge the compost toilet concept, decreasing its prestige and acceptance. It also perhaps even caused confusion due to this misinformation being spread around the village. Governmental agency strategies are more top-down and do not have the same commitment and beliefs as grass-root philosophies, environmentalism, and innovative technologies. The business and the sponsoring municipality were probably critical of the other models and perhaps only interested in reaping profits and gaining popularity and votes. The political aspect was definitely witnessed in the community project directly prior to this village.

Even with all these problematic influences, not all was lost—perhaps something was gained in the long run. First of all, the competing technologies and organizations brought to the surface disadvantages and weaknesses of the originally-introduced brick model and that project. This new information and experience enabled innovative changes to be made to the design, and operation and maintenance approaches to all three technologies. Secondly, the dynamics of competition improved the technology, the program approach, and the skills of the investigators. Also, conceptually for the community, the new sanitation question became not only if the originally introduced brick toilet version was a successful and acceptable technology, but which model was better. A comparative analysis began to be made by the users. Literature further demonstrated that villagers do benefit-cost analysis in weighing the advantages and disadvantages of participating in new community projects. In this case, a change of their sanitation habit was the point of analysis made. Their new question was whether to change, from either the status quo practice of indiscriminate defecation in the field or from the more popular waterborne toilets, to now evaluating which of the three compost toilet types to switch to and adopt. The thought probably was "I don't like the fiberglass model, but the block model is OK, and more aesthetically pleasing and sound than those brick toilets with those worn out brick toilet shelters" (which *were* starting to deteriorate from weathering).

It was seen over the 14-year period in the village that the community became more populated, water shortages continued, and incomes continued to be limited. If these trends continue, it is believed that the acceptance of the desiccation compost toilet will increase again. As community members continue to struggle economically, and financially possibly worsen, it is further believed that the inexpensive compost toilet will be seen as the only current technology that is practical, affordable, and buildable in the rocky terrain where the water-borne system has problems in its construction and use. This is why the local architect only promotes the desiccation toilet.

Scientific versus indigenous health beliefs were investigated by asking users about their possible use of natural medicines. In few cases, users indicated that they had non-scientific beliefs concerning health and sanitation. Various individuals, though, stated that they use natural medicine, which was considered an overt sign of sub-conscious health and disease theory beliefs based on the Greek humoral system, adopted in Latin America hundreds of years ago.

Other issues confirmed were social beliefs concerning sanitation practices, waste handling, and the process of change with the individual and community. Changing community demographics were shown to influence and increase the rejection of the newly-introduced sanitation technology. Social factors investigated were more, and specific to the individual, not the community. Influential social factors were found to be "grounded in science and the physical world" with lesser ones based on philosophical constructs or lofty thinking. Theorizing was considered *boring* ("rollo") to the practical Mexican people and such talk and discussion to be concepts *in the sky* ("en las nubes"). It was seen that the Mexican user's perspective, beliefs, and actions were based on their physical reality and their struggle to improve their lives, in particular in this case for their need for basic services to meet their basic human needs for sanitation and health. Practical desires such as comfort, convenience, cleanliness, and distance (proximity and separation) were factors found to be more motivational than a desire to improve health. The practical problems with the toilet such as odors, insects, aesthetics, waste handling, poor use based on inadequate knowledge, training, and experience were identified as key factors in acceptance or rejection and in the success or failure of the toilet.

Although an attempt to link the sanitation activity to water supply and water quality improvements were made, but not extensively implemented, it was shown that the linkage is critical for sanitation technology and program acceptance and sustainability. Although organizational and program theories and factors required for successful developmental project implementation were not the specific theme of the investigation, they were reviewed on a broader regional and international basis and a long list of critical factors was provided.

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Uncertainty in social factors, motivations, and willingness of individuals to participate created uncertainty in the program methods and approaches. This resulted in an approach that was based on use of pilot projects to give people real experiences, combined with outside technical support, with feedback from users incorporated into the project in a behavioral-change format approach to introduce new technology. It was set forth that investigators have to feel comfortable with uncertainty and not hasten to make judgments based conceptual theories, but instead to stay grounded in the practical realities of the sanitation activity and the people's stated desires, but confirmed with their behaviors.

A simple graphical form (no text) was developed for use by community technical support workers to pictorially represent field assessments of the status of the technologies' acceptance and success as its use proceeds. Simple field technical approaches and sampling kits were used and modified to be able to make technical assessment right in the field within one day's time. This approach will enable technicians to provide feedback immediately to users, which is key to the sustainability of this technology.

P.11 Conclusions

The conclusions were:

1) Overall project had limited success and limited acceptance.
2) Total coverage of community was low, estimated between 5 and 20 percent, perhaps higher, considering replacement of one toilet type with another would result in *no net loss.*
3) There were some tremendous successes at some households with high levels of treatment obtained and strong user satisfaction.
4) There were some toilets that had long term acceptance, though even in most of those cases the technology was viewed as an intermediate step. Regardless, many families continued to use the technology, some because they had no other feasible options. In a sense, they were "stuck" with the technology.
5) Design improvements incorporated user concerns, most importantly the toilet basin, to improve its aesthetics.
6) Acceptance and success can be increased mostly by improved operation and maintenance, and largely through use of adequate, sufficient additive, design, inclusion of an additive reservoir, an automatic additive delivery system, an improved and easily maintained toilet basin and easier, more-agreeable vault access and waste removal and disposal and re-use techniques.
7) Acceptance may be achieved with significantly increased valuation by the community of this technology's benefits versus its cost. Successful project implementation methods will be needed also.
8) Some elements in the definition of benefits, success, and acceptability of the toilet by community members were the absence of offensive odors or insects, the actual household's degree of need for a non-waterborne toilet, and the benefits of convenience, comfort, and privacy.

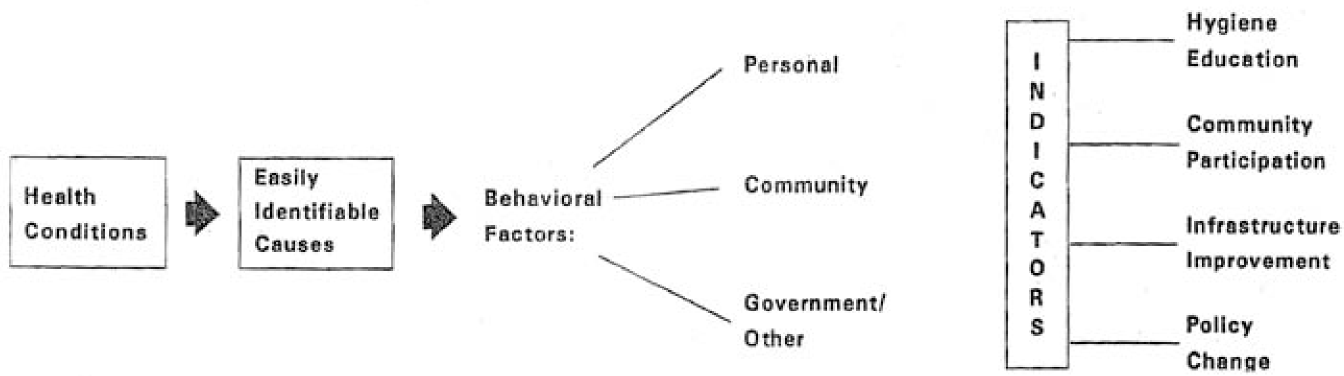
9) The absence of social stigma and community criticism from neighbors was considered an influence on acceptability by some households, and its presence decreased acceptability and possibly rejection.
10) It appeared that the community's perception of their sanitation needs changed. Initially, the most predominant question was if the brick model of the toilet worked. With the introduction of the other model types, the new question arose as to which of the three model types was best. In other words, the community began to do comparative analysis and further develop their concept of sanitation and hygiene. Attitudes, beliefs, and practices evolved.
11) Waterborne sanitation options continue to be desired as the preferred option, where and when water was available.
12) This technology proved to be a low cost, low-maintenance, more-or-less appropriate technology, especially the brick models (U.S. $100 to $250), the block models ($200 to $300), and much less the fiberglass models (estimated U.S. $800). This was especially the case where households understood its values and requirements and accepted the non-waterborne nature of the toilet.

The improved alkaline desiccation compost toilet in central Mexico is a technology with limited acceptability at this time. Improved valuation of the benefits of this toilet versus its costs compared to other options available is necessary, before greater and broader acceptance can be expected. Improved design, operation, and maintenance standards and practices can increase technology success and acceptability. More importantly a management system that obtains and incorporates user feedback is necessary. Since rapid, mass, and poor implementation and evaluation of rural sanitation projects have been shown to yield numerous failed results, moderately-rapid assessment (13 to 25 months) should be required in rural community sanitation projects, where change is slow and difficult. The very limited acceptance was probably largely due to the villagers' predominating desires for a modern, waterborne toilet. As population densities and water shortages increase and unimproved economics continue, the acceptability of the proven waterless desiccation toilets should increase and the initial weathering seeds and plants from the pilot projects could begin to sprout again, possibly even without any more exterior support (the science of technical success and social acceptance is complex—see the appendices for other elements that must be considered).

APPENDIX Q

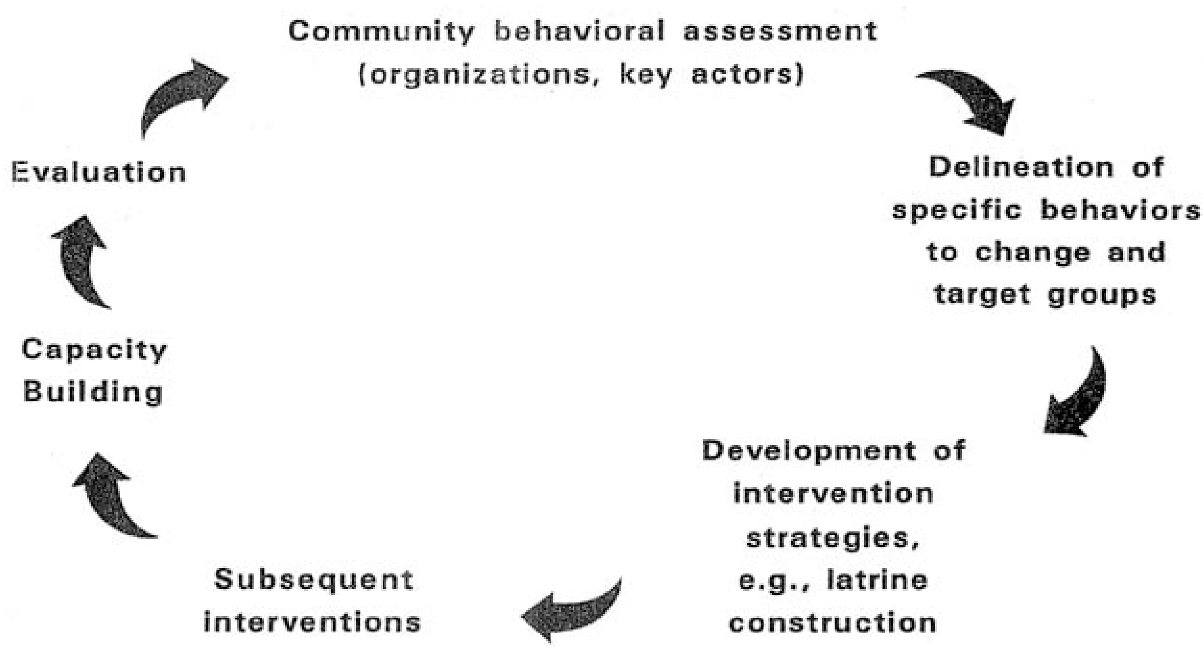
BEHAVIOR CHANGE PROGRAM ELEMENTS

HEALTH BEHAVIOR MODEL:
RELATIONSHIP OF BEHAVIOR TO PROGRAM INTERVENTIONS



Source: Yacoob, Braddy and Edwards, 1992.

THE BEHAVIORAL CHANGE MODEL



Source: Yacoob, Braddy and Edwards, 1992.

The following are considered important behavioral & other components of developmental projects & acceptable attributes of sanitation technologies identified in the following Study: Behavior In Water Supply and Sanitation, May Yacoob and Linda M. Whiteford, Human Organization, Vol. 53, No. 4, 1994:

1) Development as an *Adaptive* Change:

Specifically: Accept the reality and interconnectedness of change and stress need for technologies & innovations that can be adapted to solve locally felt needs

Behavioral change is a learning process (that takes place through communication between development practitioners &community members). Development and change are a process of modification to solve problems relating to what people currently do rather than as a means by which "newer" & therefore better technologies *replace* existing technologies or interventions.

2) Different Groups of People have Differing Models for Understanding & Interpreting their Perception of Reality

Specifically: Based on existing body of indigenous knowledge

Development practioner usually considers scientific model
Community models built upon generations of experience
i.e. Bangladesh hand washing analysis:

Soap seen as cosmetic agent rather than one to remove microorganisms
Washing serves both physical and spiritual needs

3) Gulf between Ideal and Actual Behavior and between Intended and Actual Outcomes

Specifically: Employment of constant feedback

Thus a system that uses feedback as a continuous process to permit learning from experience is critical to long-term success. Program staff must adapt the program to behavioral information so that project activities respond to community needs.

Other Considerations:

- too little scrutiny to types of technology acceptable to a given community
- too little scrutiny to hygiene education needed to support the chose option
- coverage goals have dominated project thinking, as opposed to behavioral considerations (usage, upkeep, hygiene practices)
- Technical nature of sanitation projects causes the following sociocultural aspects of sanitation projects to be neglected: hygiene education to assist community members learn how to use the sanitation facility and how to keep them clean.
- Starting point of any sanitation project should be an inventory of community health knowledge, attitudes and practices relevant to water supply and sanitation improvements. This will indicate acceptable technologies
- Best way of assessing the acceptability of technology is through pilot programs that offer more than one technology option (Cairncross & Macoun, 1990)
- People can and do change their behavior (Stanton & Clemens, 1986, 1987). In one study, handwashing resulted in a 26% reduction in diarrheal diseases.
- Unknown the extent to which the participants will continue practicing new behaviors after the project ends
-

Reasons for lack of clarity on how to establish behavioral change program as part of health-related program

- lack of basic information about existing hygiene practices and beliefs related to improved WS&S
- gap between research & field experience with effective hygienic processes & practices(Levine 89)

APPENDIX R

SOCIAL FACTORS BASED ON INTERNATIONAL LITERATURE REVIEW (CATEGORY FORMAT)

SUB-CATEGORY/#	SOCIAL FACTOR CATEGORY
INTERNAL	
A	Sanitation Customs
B	Community
C	Conceptual
D	Individual
E	Other customs
EXTERNAL	
F	External
FACILITY	
G	Facility
H	Operation
I	Maintenance
PHYSICAL WASTE	
J	Waste characteristics
ALL OTHER	
K	All Other

APPENDIX S

SOCIAL FACTORS BASED ON INTERNATIONAL LITERATURE REVIEW (INDIVIDUAL FACTORS)

	EXTERNAL FACTORS	
F	External	
		Political factors
		Commercial
		Change agents: non-profit groups, government, etc.
		- + or – reputation of group(s)/associated internal representative
		- implementation procedure[ii] or perception of program
		- linkage to other felt needs: i.e. water supply
		- gained access to other resources (or just want "piece of pie")
		International economic and other factors
		Migration/Temporary status of home/Fear of eviction
	FACILITY FACTORS	
G	Facility	The comfort of use of the seat & urinal
		General comfort of superstructure (headroom, walking space, etc.)
		Comfort and convenience from protection from weather
		Convenience of being indoors
		Visibility of waste
		Presence of acid on seat
		Sufficiency of walking, turning & standing space of shelter
		Aesthetics & architecture of the toilet superstructure
		- consistent with personal & community values
		- consistency with architecture & value of home
		Location of facility (i.e. distance from home, water, previous IDF local, etc.)
		Permanent or temporary nature of home & toilet
		Compatibility of users using individual toilet/community toilet
H	Operation	
		Need to place blanket of soil on bottom of empty new chamber
		Need to introduce a dry absorbent after every (fecal) use
		Need to close insect-proof seat cover after every use
		Need to level contents periodically
		Need to place blanket of soil on top of finished chamber
		Need to open trap door & replace after emptying compost
		Need to handle and re-use or dispose of composted material
		Success of treatment of waste
		Conformity of operation with previous habits & customs that individuals desired to continue.
I	Maintenance	
		Need to pour water into urinal to clean it (possibly optional)
		Need to clean the toilet basin walls & urinal of any fecal matter
		Need to replace or repair urinal discharge hose
		Need to replace toilet basin periodically
		Need to replace urinal periodically
		Need to provide waterproof grout to brick surfaces periodically
		Possible need to introduce insect repellant

	PHYSICAL WASTE	
J	Waste characteristics	
		Presence of offensive odors
		Presence of offensive flies, mosquitoes, roaches & rodents
		Visual characteristics of waste
		Visibility of waste
		Location of collected waste
		Location of waste during treatment process
		Location of discharged waste
		Separation of feces and urine
		Presence of harmful microbial organisms in waste
	OTHER FACTORS	
K	All Other	
		Capital, O&M and other perceived costs vs. benefits
		Temporal issues: time of day for defecation; migrant worker, etc

[i] The following perceptions, preferences, beliefs, attitudes, incentives & practices towards health-related issues were based on a study of seven Latin-American communities in the following countries: Guatemala, El Salvador, Nicaragua, Colombia and Mexico (Chan Kom, Yucatan). The study was entitled Sociocultural Aspects of Water Supply and Excreta Disposal, Appropriate Technology for Water Supply and Sanitation, Mary Elmendorf and Patricia Buckles, World Bank/December 1980.

Condtions Associated with Poor Health:
- Presence of odors from sanitation facilities
- Presence of flies
- Presence of high fecal contamination in water
- Presence of worms (in waste in facility?, body? or in stool?)
- occurrence of diarrhea

Conditions associated with Healthy Environment
- fresh air or good air
- good climate
- accessibility to highway (in case anything goes wrong)
- in crowded settlements:
- - environment that allows for privacy & characterized by good relations with neighbors

Conditions associated with Un-healthy Environment
- poor sanitation
- dead animals contaminating water source

Conditions of water that indicate that it is considered clean:
- color
- taste
- smell
- piped, covered
- introduced by government health agency

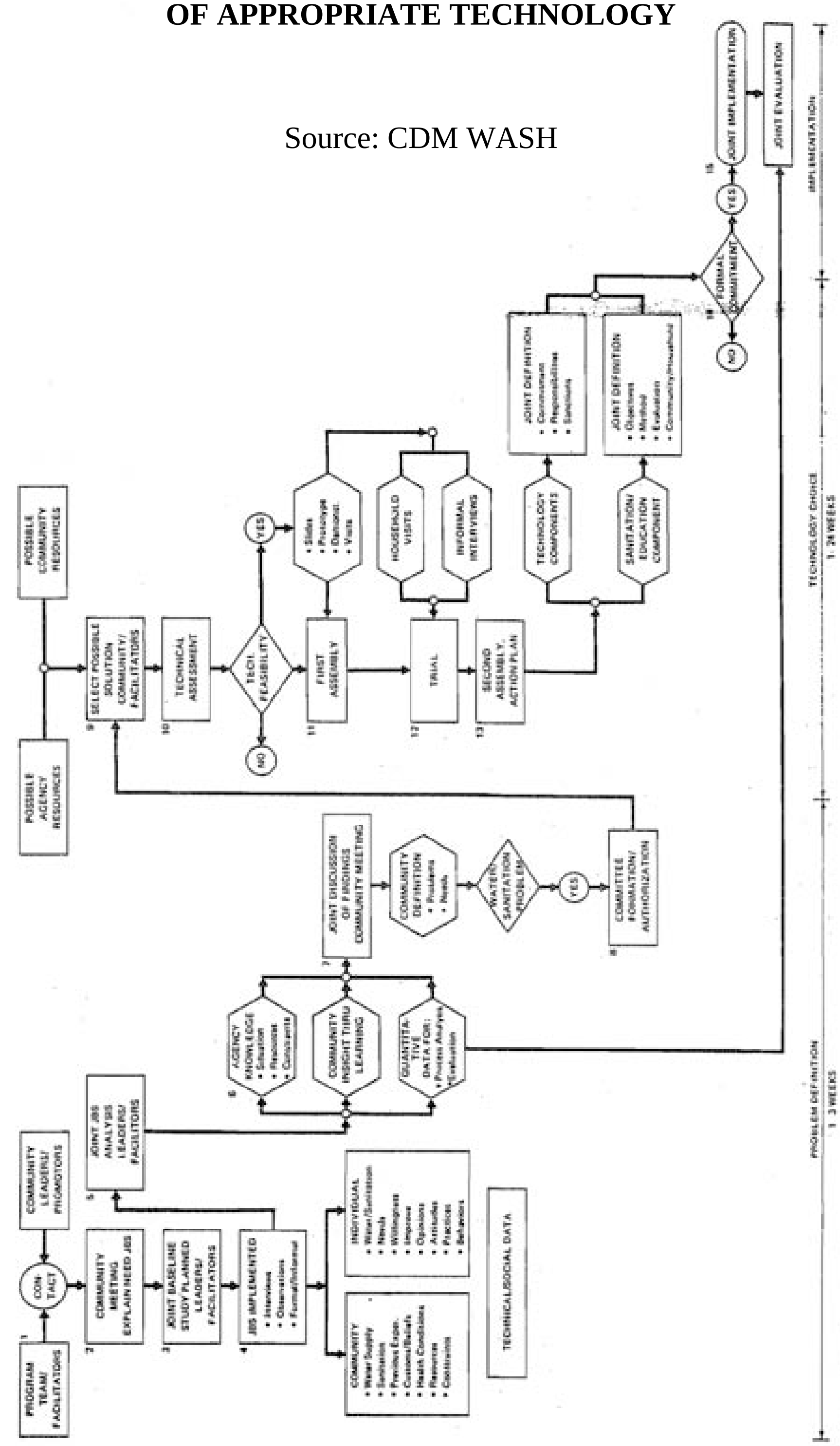
Qualities of Water Appreciated (desired/believed important):
- abundance
- proximity

Factors objectionable associated with Improved Water Supply:
- Cost
- Crowding at public water taps
- Quarrels & Problems with neighbors due to sharing same public tap (therefore, socializing not considered benefit)

APPENDIX T

METHODOLOGY FOR INTRODUCTION AND ADOPTION OF APPROPRIATE TECHNOLOGY

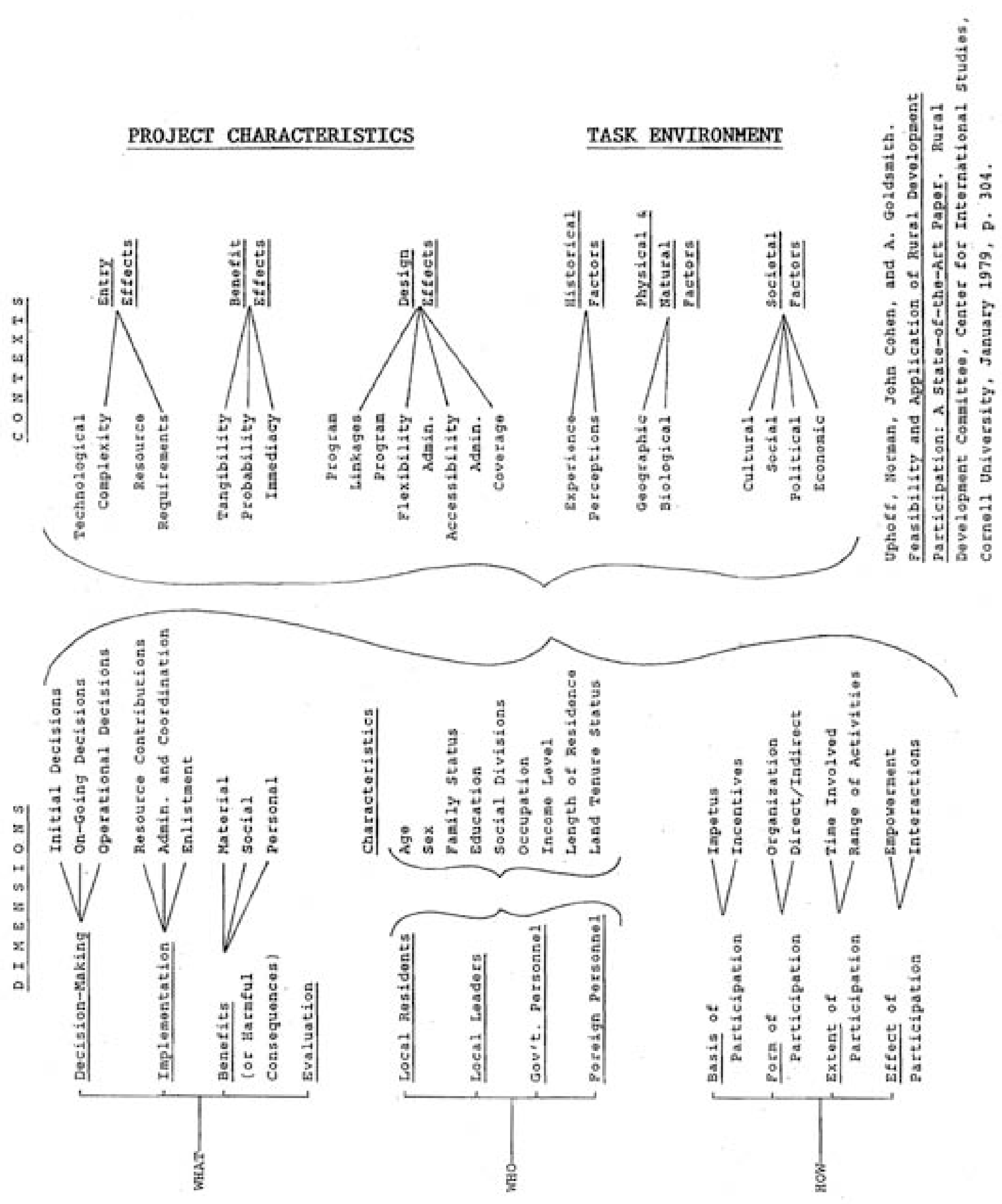
Source: CDM WASH



Methodology for Introduction and Adoption of Appropriate Technologies in Sanitation

APPENDIX U

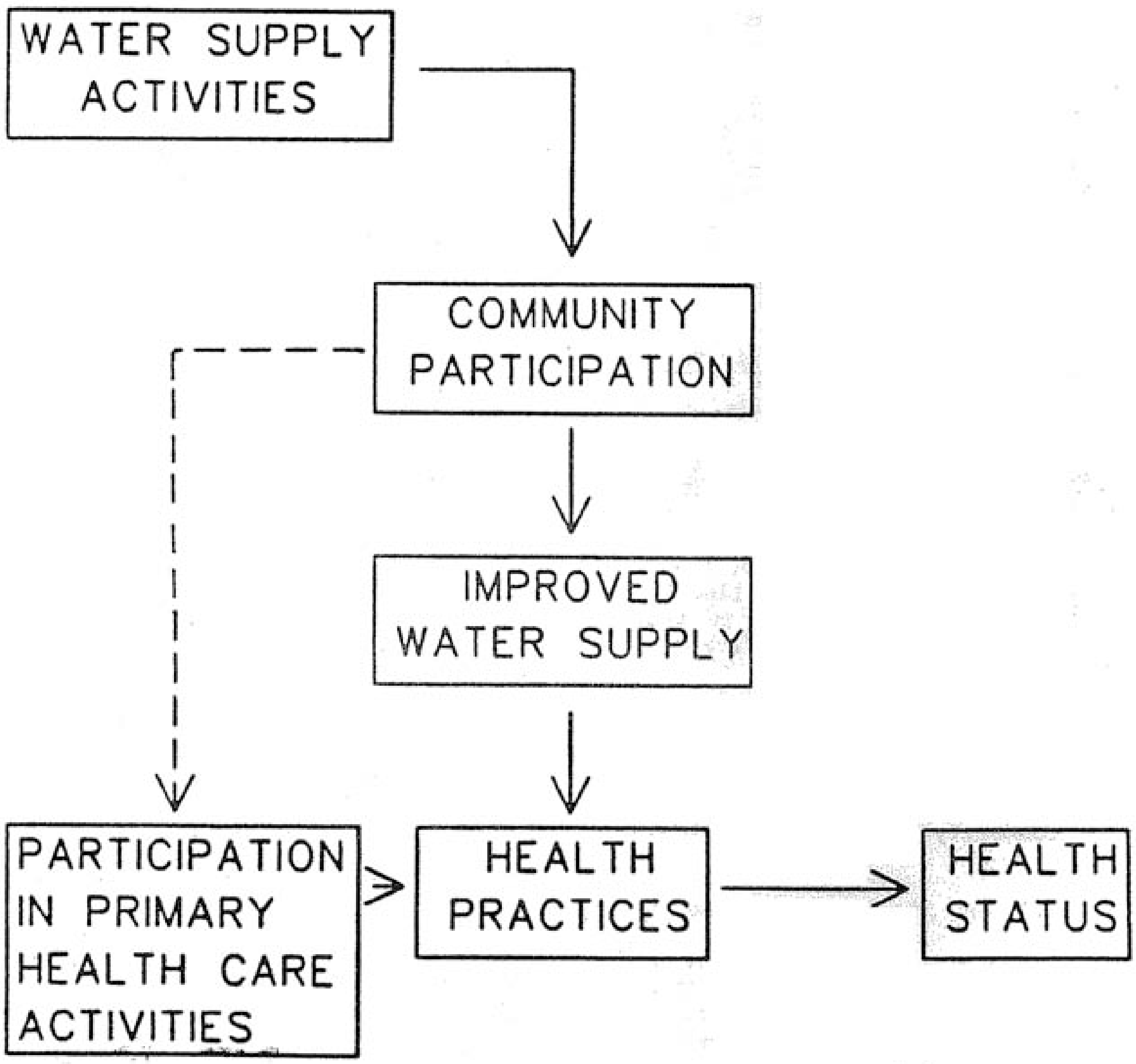
CONTEXTS AND DIMENSIONS OF PARTICIPATION



Source: Eng Eugenia, et.al. *WASH Technical Report No. 44(Community Participation in … Togo)*. Washington, D.C.: U.S. Agency for International Development, 1987.

APPENDIX V

RELATIONSHIP BETWEEN WATER SUPPLY ACTIVITIES AND COMMUNITY PARTICIPATION



Source: Eng, et.al.. WASH Technical Report No. 44(Community Participation in … Togo). Washington, D.C.: U.S. Agency for International Development, 1987.

APPENDIX W

FIELD FORMS FOR INTERVIEWS, INSPECTION, AND SAMPLING

Part 1) Entrevista de Entrada (*en la puerta)* (Curbside pre-interview)

Introduccion
(INTRODUCTION)

1. Somos de 2 Universidades haciendo una investigacion tratando de mejorar los proyectos de sanaemiento y salud.
   (We are from two universities doing an investigation to improve health and sanitation projects.
2. Deseamos pedir su consentimiento a platicar sobre el sanaemiento (Si fueran de acuero, firmaran atras de un foto).
   (We would like to request your permission to discuss with you sanitation (If they were in agreement, at a later point when a photo was taken, the family member signed the back of the photo).
3. Atencion familiar (Preguntar sobre el bienestar de la familia)
   (Personal Attention: Inquiry as to welfare of the family (small talk).
4. Usted tienne un tanque de agua? Filtro de aguas grisas? Bano?
   (Do you have a water tank? Graywater filter? Bathroom?)
5. Que tipo? Si no, como hacen sus necessidades privadas?
   (What type (of bathroom)? If not, how do you take care of your private necessities?)
   (It is unclear if this question was actually asked, because of sensitivity)
6. Podemos ver el bano?
   (Can we see the bathroom?)

Part 2) Platica (General Dialogue)

Seven questions concerning the family's forms of participation, health and benefits and cost (See Figure P.6).

Part 3) Cuestionairo al repecto a Operacion y Mantemiento (Operational and Maintenance Questionnaire)

Ten Questions about Operational Requirements, Potential Problems and Hygiene (see Figure P.7).

`

Part 4) Physical Inspection of the Dry Toilet (Alkaline Desiccation Toilet)

Inspeccion Fisica de los Sanitarios Secos

Number:____________

Communidad:______________________________ Municipio:______________________________

Fecha:____________________ Tiempo Iniciado:____________________ Tiempo Terminado:____________________

Padre de la Familia:______________________________ Madre de la Familia:______________________________

#	**Unidad de Medida**	**Lo Tiene**		**Tamano**	**Condicion**			**Observaciones Problemas y Soluciones**
		Si	**No**		**Buena**	**Regular**	**Mal**	
PISO	m x m							
CHAFLAN	cm							
CAMARAS	m x m							
* tabique								
* tabicon								
* adobe								
* aplanado								
* fibre de vidrio								
COMPUERTAS	cm x cm							
LOSA	(m xm)							
TAZA	cm							
* y mangera	pulgadas							
* asiento	normal/chica							
* tapa "sellada"	normal							
*mijitoria insertada	normal							
POZO								
de absorpcion								
* diametro	cm							
* grava	cm							
* plastico tapada	n/a							
* arena	cm							
* profundidad total	cm							
MIJITORIO								
* y mangera	pulgadas							
* garafon	litros							
CASETA								
Muros	m xm							
* provisional								
* tabique								
* tabicon								
* adobe								
* fibre de vidrio								
Ventana	cm x cm							
* herreria								
Puerta								
Pintura								
TECHNO								
* provisional	m xm							
* carton								
* galvinazada								
* losa								
TUBO de respiracion	cm							

Inspeccion Realizada Por____________________ Revisado Por____________________ Supervisado Por____________________

Part 5

Entrevista de Salida
(Exiting Interview: Questions while on the way out the Door)

1. Hay algo que no platicamos?
   (Is there anything that we did not discuss?)
   Note: Family members did not usually respond much to this question, perhaps because there was already a very through interview(dialogue).
2. Acepto o no acepto este modelo de bano? Porque? Acepto otro modelo? Cual?
   (Was the bathroom model acceptable to you? Why? Choose other model? Why?)
   Note: This question appears not to have been asked usually, because at that point of the interview, the family member has already provided information that should have made the answer to that question clear. Also, that could have been considered a very direct question and it could have uncomfortable.
3. Podemos sacar una muestra de abono? Cuando?
   (Can we remove a compost sample from the toilet? When?)
4. Usted tiene un opinion libre que desea compartir con nosotros?
   (Do you have an opinion about the compost toilet that you would like to share?)

Part 6 and 7) Laboratory and Solvita Sampling

1) The sample was composited (mixed thoroughly to ensure a homogeneous sample)
2) A portion of the sample was used for the Solvita® test and a portion for the sample to return to the laboratory

Part 6) Solvita Test

See Tables 7.6 and 7.8

See Figures 7.7, 7.8, 7.9. 7.10, and 7.13

See Appendix A

3) The unused portion of the composited sample was returned to the vault to maintain it in its original condition until time for transport to the laboratory.

Part 7) Other Field and Laboratory Testing

4) Just prior to the return trip, a final sample was removed and placed in a container to bring to the laboratory
5) The pH, waste temperature, ambient temperature, the air temperature inside the shelter, and the sample's water content was measured on-site. See sample forms labeled PART 7 that follows in English and Spanish.

`

PART 7

SAMPLE COLLECTION (ENGLISH VERSION)

Sample Collection

Community:____________________ Municipality:____________________

Date:____________________ Father of Family:____________________

Hour of Initiation:____________________ Hour of Completion:____________________

#	Parameters	1	2	3	Average	Notes
1	pH					
2	Air Temperature (Ambient)					
3	Temperature Inside the Shelter					
4	Temperature of Guarantee (Compost)					
5	Humidity					
6	Solvita Kit Test					
	a. CO_2 Reading					
	b. NH_3 Reading					
7	Seed Germination Test					
	a. Initiation					
	b. Completion					
	c. Height					
8	Family Observation					

1. Rain: Yes or No 2. Light: Strong Sun, Obscured Sun or Little Sun 3. Heat: Hot, Moderate or Cold 4. Atmospheric Humidity: Heavy, Moderate or Minor

PART 7

SAMPLE COLLECTION (SPANISH VERSION)

Collecion de Muestras

Comunidad:______________________ Municipio:______________________

Fecha:______________________ Padre de Familia:______________________

Hora de Iniciación:______________________ Hora de Terminar:______________________

#	Parametro	1	2	3	Promedio	Notas
1	pH					
2	Temperatura Ambiental Exterior					
3	Temperatura Ambiental Dentro					
4	Temperatura de Abono					
5	Humedad					
6	Prueba de Juego de Solvita					
	a. CO_2 Lectura					
	b. NH_3 Lectura					
7	Prueba de Semilla					
	a. Iniciacion					
	b. Terminar					
	c. Altura					
8	Observacion de Familiar					

1. Lluvia: Si o No 2. Luz: Sol Fuerte, Sol Oscuro o Poco Sol 3. Calor: Caloroso, Medio, o Frio 4. Humedad: Mucha, Meida o Poco

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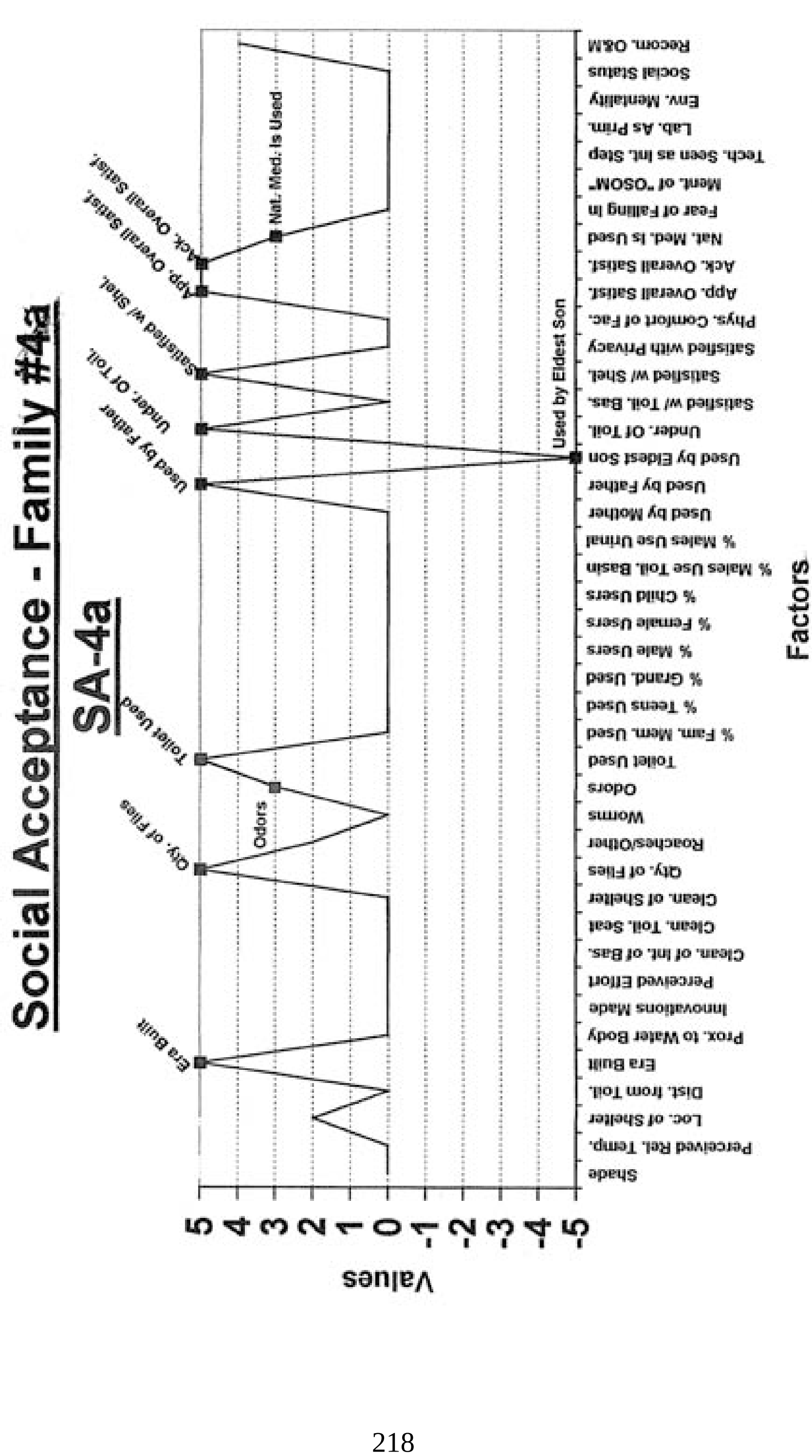
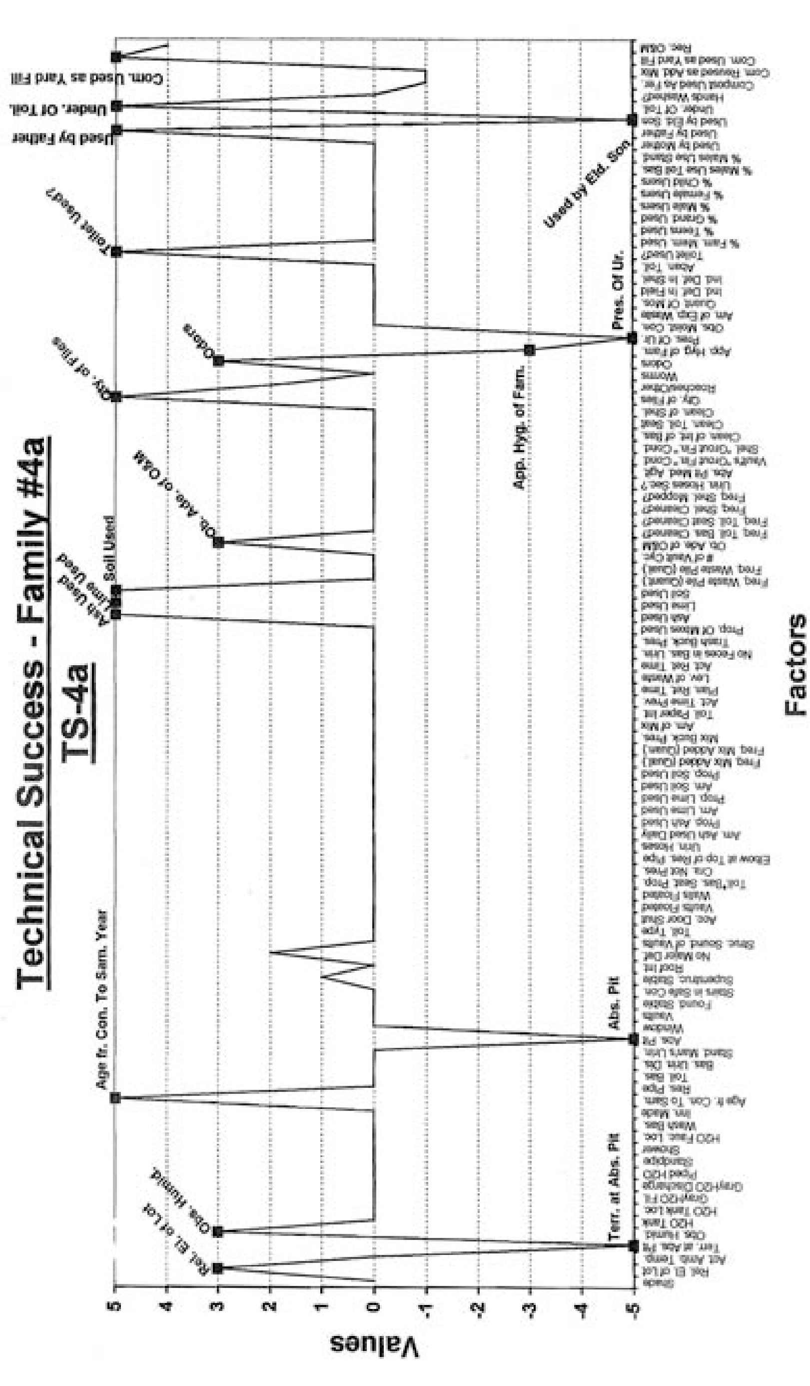
APPENDIX X

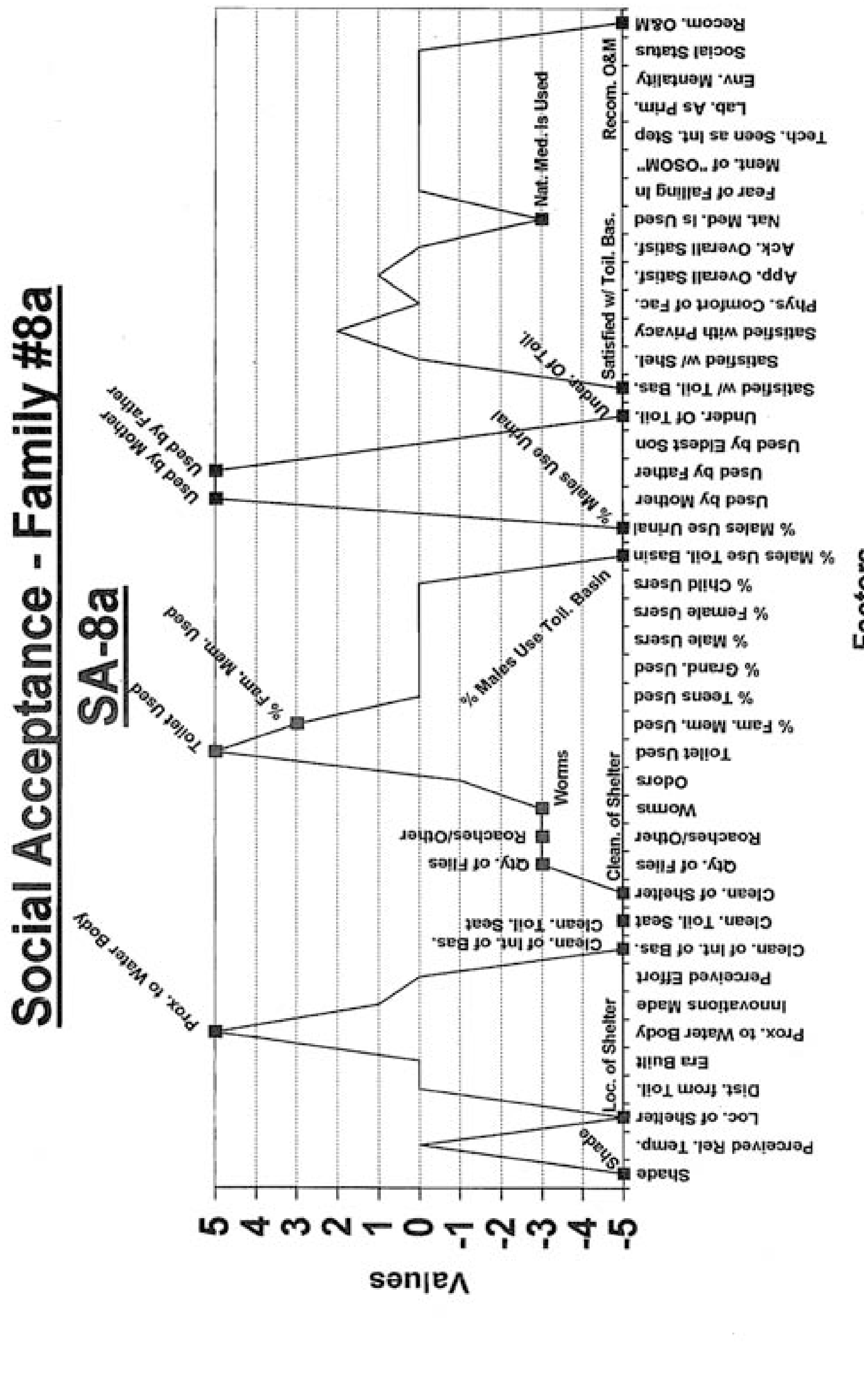
SOCIAL ACCEPTANCE AND TECHNICAL SUCCESS GRAPHS (FAMILY 4)




Technical Success - Family #4a
TS-4a
Values
Factors
Rel. El. of Lot
Obs. Humid.
Terr. at Abs. Pit
Age fr. Con. To San. Year
Abs. Pit
Ash Used
Lime Used
Soil Used
Ob. Ade. of O&M
App. Hyg. of Fam.
Qty. of Flies
Odors
Pres. Of Ur.
Toilet Used?
Used by Eld. Son
Used by Father
Under. Of Toil.
Com. Used as Yard Fill

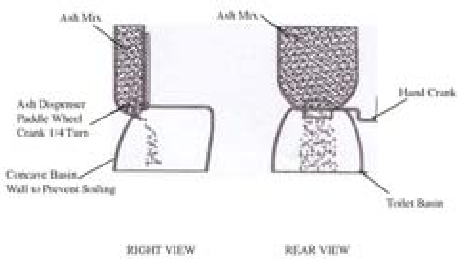
APPENDIX Y

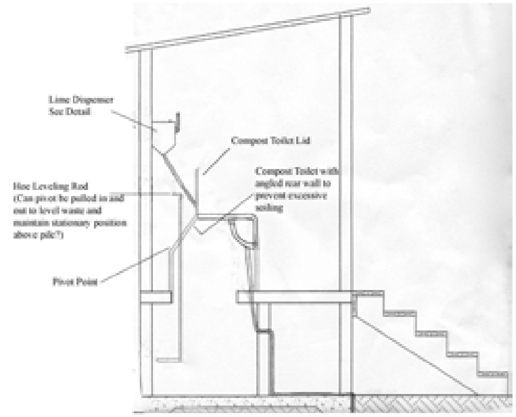
SOCIAL ACCEPTANCE GRAPH (FAMILY 8)



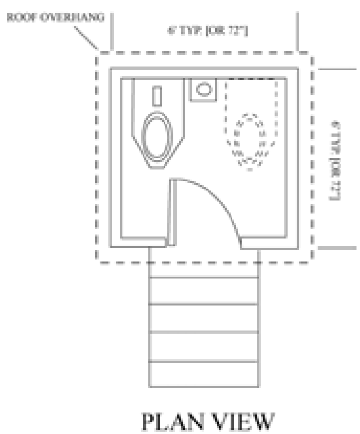
APPENDIX Z

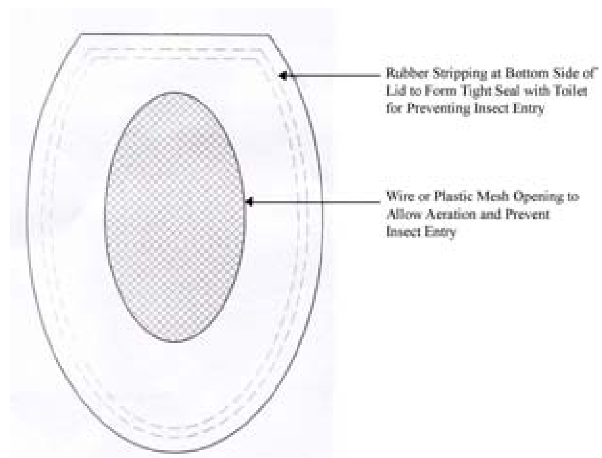
IMPROVED DESIGN FEATURES





(A) **(B)**





(C) **(D)**

Notes:

A) New Toilet Basin Type 1 with Reservoir for Additive and with Slanting Rear Wall of Toilet Basin to lessen soiling; B) Side View of Toilet Basin Type 2 —Slanting Rear Wall of Toilet Basin to lessen soiling, separate lime dispenser and pivoting leveling hoe; C) Plan View of Desiccation Toilet and extra front storage area; D) New Toilet Seat Design for Prevention of Insect Entry (Figures by Students of Edison College Engineering Class of Author)

APPENDIX AA

FIBERGLASS TOILET APPURTENANCES

Below are shown examples of different appurtenances of the fiberglass toilet. From Figure AA.1 it can be seen that this toilet model can be maintained well, however, its other problems of high shelter temperature and strong odors still persist. In the shelter, on the left side is the trash bucket where it is required that the toilet paper be disposed. (It is a common practice in Mexico for toilet paper to be disposed of outside the toilet to prevent clogging of the pipes which are often undersized.) On the right is the bucket of ash.

Figure AA.1 Well-Maintained Fiberglass Toilet with Trash Basket and Additive Bucket

Figure AA.2 shows the waste basket and the bucket of additive, which appears to consist mostly of wood ash. Also in the picture, an improperly-located black plastic urine hose can be seen through the toilet basin opening. Accessing the hoses (when the vault is active) is probably a very unpleasant task. Figure AA.3 shows two fiberglass toilet removable waste receptacles. When they are filled, they are removed from the toilet and placed in the yard. Sometimes the family has multiple recepticles, so that for example, three can be used and dry out in rotation.

Figure AA.2 Waste Basket, Urine Discharge Hose inside Vault (middle), and Container of Additive consisting principally of Ash

Figure AA.3 Two Fiberglass Toilet Removable Waste Receptacles Stored in the Yard—One Closed and One Left Open to Aerate

APPENDIX BB

MODIFIED 1988 CONSTRUCTION BUDGET (BRICK TOILET)

Double-Vault Construction				
Items	**Quantity**	**Units**	**Cost per Unit**	**Total Cost**
Cement	4	Bags	$3.63	$14.52
Thick Wire/Rebar	15	Kilo	$0.79	$11.85
Thin Wire/Tie Wire		Kilo	$1.00	$1.00
Bricks	350	each	$0.20	$70.00
Quick Lime ($CaOH_2$) for Brick Mortar	2	Bags	$1.82	$3.64
Quick Lime as 1 of components of Daily Additive	1	bag	$1.82	$1.82
Roof Panels (.82 x 1.89)	3	sheets	$8.64	$25.92
Store-bought Toilet Seat and Cover	1	each	$13.64	$13.64
Manufactured Toilet Basin	1	each	$50.00	$50.00
Flexible Hose (for urine discharge)	4	m	$1.36	$5.44
Flexible Hose (for urine discharge hose)	1	each	$1.00	$1.00
Clamps / Braces for Hose	2	each	$1.00	$2.00
Screws	1	L.S.	$1.00	$1.00
Hinges	2	each	$1.00	$2.00
Miscellaneous Items	1	L.S.	$5.00	$5.00
Sand, Gravel & Other Local Materials by Family	1	L.S.	0	0
			Sub Total	$208.83
			Contingencies	$41.17
Vault Construction and All Other except Shelter			**Total**	$250.00
Shelter Wall Construction				
Brick, Block or Adobe	400	each	0.4	$160.00
TOTAL CONSTRUCITON COST				$410.00

APPENDIX CC

GEOGRAPHICAL, GEOLOGICAL, AND SOCIOECONOMIC CHARACTERISTICS

Geographical Conditions

- Latitude N 19 degrees
- Longitude W 99 degrees
- South/Southwest of Mexico city
- Altitude is approximately 1,000 meters
- Tropical weather, temperature (annual med.) 27 deg C
  (70 to 95 degrees year round in lower lands)
- Annual precipitation 1,000 mm (39.4")

Geological Conditions

- Morphology legibly corrugated
- Valley "Aluvial Intramontano"
- Sedimentary marine continental rocks, igneous extrusive rocks, and metamorphic rocks in less proportion
- Sediment marine rocks in their majority belong to the Mesozoic group (usually chalky and gray)
- Stratified in massive thick layers, fossil-like porous rocks and cavernous-like rocks underlie
- Cement-like rocks of fine grain are stratified in thin layers

Source: Valeco, Artemio. *OLBS Geological Study*. Mexico City: Engineer Artemio Valeco Private Consultant Engineer, 1989.

Socio-Economic Characteristics

- Typical Daily Wage: $10 to $20 U.S.
- Common Employment: Construction Work, Agricultural Work, Tourism
- Typical Highest Education Level Attained: Secondary Education (*Secundaria*) – 9th Grade
- Local Crops: Corn, Rice, Sugarcane, Roses

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APPENDIX DD

PROJECT INITIATION AND DISENGAGEMENT

BEGINNING PROJECT INVOLVEMENT WITH THE COMMUNITY: CHECKLIST

Before introducing the project to the community, the extension agents undergo six days of intensive training in how to plan, prepare, and implement training programs. Then they, with the assistance of the project staff, follow these steps in the community:

- ✓ Meet and establish rapport with the village elders
- ✓ Hold an initial community meeting to explain the project
- ✓ Meet with small groups of villagers for a Q and A session
- ✓ Assist the community to carry out a survey on resources and potential technical feasibility
- ✓ Hold a second community meeting to explain available water system options and obtain the community's commitment to the project

MONITOR AND DISENGAGE: CHECKLIST

Before disengaging from the village, the extension agent should:

- ✓ Gradually cut back visits
- ✓ Reassure the community that it can solve problems on its own
- ✓ Provide auxiliary training support to the village water committee as needed
- ✓ Help the water committee evaluate and improve its performance

Source: Yacoob and Roark, 1990

APPENDIX EE

MEXICAN HISTORICAL INFLUENCES

Below is some historic information about Mexico. All this information has been obtained from Alan Riding's classic work on Mexico entitled *Distant Neighbors, A Portrait of the Mexicans* (1984). Accounting for and understanding this background is important for evaluating current events, the investigated community and general program issues.

The political issues are varied and affect how the community interacts with outsiders. It also provides a context in which Mexico can be seen.

- Mainly U.S., Mexico adapts from others based off Washington
- Successive administrations in Washington irritate and puzzle Mexico
- Mexico tries to be independent. Sees European and Asian leaders
- European and Asian countries were building neutral colonies
- Mexico's president leaves and visits 36+ nations when saying he'd stay in Mexico two to three years
- The President of Mexico courted smaller third world countries in an effort to provide leadership
- President put in effect other countries' ways as his own
- President in 1975 considered himself a third world leader
- Mexico is still economically dependent to the United States
- Shields itself from outside pressure

Cultural issues are of the utmost importance. Culture particularly affects the inner workings of the program and how individuals perceive the people and the world around them.

- Indians are proud of their past but ashamed of today
- 70 percent of adults had 6 years of primary education
- Government social welfare programs are riddled with corruption
- Need for decentralization
- U.S. help can't completely take over Mexico, or it won't survive
- Mexico (Mexicans) adapts from others–Washington (Western society)
- 15 percent of all Mexicans are illiterate. However, 25 percent of those are functional illiterates.
- Research is poorly financed
- Good teachers are hard to find
- Conflict among tribes and government over villages
- Project community is mostly, if not all, Mestizo

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The environmental conditions present the physical reality in which the sanitation program is conducted. The health conditions affect the primary objective of the sanitation project—health.

- Health of rural/urban poor way below minimum standards
- 60 percent are under-nourished
- Many Indians still believe in "Curanderos" (Medicine Men)
- In 1970 about 75 percent of the population lived in homes without drainage
- The highest death rate in the community revolved around the children; 5 percent of children died
- Mexicans frequently prescribed medicine for themselves in rural areas
- Absence of medical doctors and medicine–Herbal cures are believed to help everything
- Rural/urban poverty lead to malnutrition, avoidable diseases, inadequate housing, and functional illiteracy
- Indians suffer from parasites, respiratory ailments, and malaria
- Principal cause of death is pneumonia
- Vaccination program largely eliminated malaria, typhoid, and measles

The overall economic situation affects the capacity of the community to be able to afford or not afford the cost associated with the sanitation project.

- In 1977, the wealthiest 20 percent controlled 54.4 percent of all income
- Annual per capital income is $2,000
- Private medicine is too expensive; Wealthy individuals fly to the United States for medical care

Also affecting the sanitation project and its participants are stereotypical personality types. Four of those personality types were identified in a Mexican community that was only one hour from Sonacala. Those four personality types are suspicious, loving and generous, advantageous, and pessimistic. These types influence the program by creating fear of outsiders and willingness to participate in the program.

APPENDIX FF.

BLOCK DIAGRAM INPUT/OUTPUT SUMMARY OF TECHNICAL AND SOCIAL DATA

Family #______Toilet #_______BR #_________Type of Toilet (circle one): Brick, Block or Fiberglass

☐ Adults   Qty._____ Age/s:____________________

☐ Teenagers   Qty._____ Age/s:____________________

☐ Children   Qty._____ Age/s:____________________

Lime, Ash and/or Soil Additive Use:
☐ Heavy ☐ Moderate ☐ Light

Insecticide Use______________________________

INPUT →

Toilet Paper or Corn Cob

Cleanliness

Ventilated Seat

Respiration Pipe

Level of Waste
In Vault

Exposed Waste

OUTPUT →

Date First Vault Began____/____/

Date First Vault Closed____/____/_______

Date First Vault Contents Removed____/____/____

Actual Retention Time (Calculate Below)_____________

Recommendations

Vector Attraction
- A1 Odors
- A2 Mosquitoes, Flies, Roaches, Worms, Scorpions, Other
- A3 Urine Above Ground/Feces
- A4 Vector Attraction (Reduction/Potential)

General Waste Characteristics
- B1 Depth of Feces (in Vault) Inches = _______________
- B2 % Vault Depth Used = __________________________
- B3 Temperature Air, Field (Degrees F) = _____________
- B4 Temperature Waste, Field (Degrees F) = ___________
- B5 Moisture Content (Field)(Lab-5, 10 day) = (   ), (%)
- B6 pH (Field), (Lab) = (   ), (   )

Trade Compost Criteria
- C1 Total C% = ___________________
- C2 Total N% = ___________________
- C3 C/N Ratio = ___________________

Contemporary Compost Stability
- D1 Solvita CO2 = __________
- D2 Solvita NH3 = __________
- D3 Solvita Maturity Index = ________
- D4 SOUR (5 day) (10 day) = (   ), (   )

Contemporary Environmental Criteria
- E1 Fecal Coliform (5 day) (10 day) = (   ), (   )
- E2 Fecal Coliform (Field) = (   )

End User Criteria
- F1 Satisfaction Acceptance = _______
- F2 Toilet Used (% ?) = __________________
- F3 Compost Used: ☐ Fertilizer ☐ Additive ☐ Yard Fill

Technology Status
- G1 Observed Technical Success (Field) = ____________
- G2 Determined Technical Success (Lab) = ____________

Other
Observed Social Acceptance (Field)
Determined Social Acceptance (Office)

APPENDIX GG

PARTS AND SUPPLIER FOR DESICCATION TOILET APPURTENANCES (SPANISH VERSION)

Various manufactured products, mostly toilet basins and molds, for the desiccation toilet are shown in Figure FF1. The brochure shown is from a catalogue by a local innovator and manufacturer — the Center for Innovation of Alternative Technology (CITA). The author does not endorse these products nor those of any manufacturer. The toilet basins and molds for the Sonacala project were provided by CITA and funded by the non-profit organization (Basic Services for the Americas). Also CITA provided molds which were used to manufacture them on-site once a local technician was trained and interested in becoming a "letrinero" (latrine specialist). The toilet basins and molds were of good quality and at a reasonable cost. Additionally, other simpler very inexpensive provisional techniques with plastic buckets, are available for the fabrication of the toilet basins with local labor.

The village leader (family 24) assumed the role of latrine specialist and program assistant. He was paid very small sums of money to provide technical assistance to other villagers. He was paid by toilet users to install the toilet basins and sometimes to remove and dispose of the desiccated waste when the vaults were full. Basic Services for the Americas provided him the toilet basin molds with which he built additional toilet basins and sold at modest prices to new toilet owners and existing ones who needed to replace their basins. He was trained by CITA on how to produce the toilet basins with both methods. Since he was getting close to retirement age, someone was sought to replace him and his role as program technician. No one could be found that was interested. This may not have been considered a position with much prestige. Instead, as in India, there could be some stigma related to such a position with human waste handling and classification of a such a position as a *lower class* position. *This* local technician seemed to perform this task with pride and enthusiasm.

The contact information neither for the fiberglass manufacturer nor for the governmental agency who supported the block toilet construction was known. If requested, the author could probably locate their contact information. Up-to-date and objective information on more sanitation technology appurtenances, technology choices and information may be available at www.waterandsanitation.org or waterandsanitation.net or by contacting the author.

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VITA

David has worked in various capacities in the environmental, civil, and agricultural engineering field since 1983. He has been involved in urban area rural developing settings. He has performed work in both the engineering field and also in rural development work using his anthropology and social sciences background. David's undergraduate degree is in civil engineering, his master's degree in biological and agricultural engineering, and his upcoming May 2008 doctorate in engineering science which includes a minor in civil engineering and anthropology.

The majority of David's experience and expertise is in the wastewater, stormwater, environmental, biological and agricultural engineering areas. Some of his key projects have involved the following: 1) performance of flood routings for existing and proposed conditions, 2) development of sanitary sewer evaluation survey(SSES) studies and associated sewer rehabilitation / asset management programs(AMP), 3) development of highway construction plans and costs, 4) on-site sewer system inspection, analysis, design, and NSF certification, 5) wastewater system sampling, analysis, trouble-shooting and investigation, 6) analysis, design and maintenance of constructed wetlands for waste treatment, 7) design, construction and maintenance of an irrigation system and reservoir, 8) analysis of hazardous waste and chemical treatment systems, 9) evaluation of biological remediation systems, 10) marketing / planning large diameter combined sewer rehabilitation program, 11) plan and design review for regulatory compliance, 12) quantity take-off and estimation and project budget development, 13) public speaking, grant management, and instruction, 14) marketing, general sales, real estate sales and public relations, and 15) complete organizational management for a small 501(c)3 non-profit. David is a certified as professional engineer in civil engineering in Louisiana, certified as an professional engineer in environmental engineering in Louisiana and certified as a professional engineer in Florida.

David has successfully prepared research proposals or funding awarded for various research, development and implementation investigations and projects, including from some of the following sources: 1) the National Science Foundation, 2) the Louisiana Transportation Research Center at Louisiana State University, 3) the Louisiana Department of Transportation, 4) the Basic Services for the Americas non-profit organization, 5) OLBS International non-profit organization, and 6) the NPH international non-profit organization. David has also been the author or a project engineer of various funded contracts with local municipalities and private industry. One of David's proposal papers was successful in obtaining the introduction of the Ford Foundation to the collaborating local Mexican organization. Last of all David has been involved in research since the early 1990's, in education as an instructor or facilitator since the 1980's, and in service programs since the 1970's.